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CHILDREN IN THE FIRST, THIRD, AND FIFTH GRADES IN A SELECTED ELEMENTARY SCHOOL WERE EXPOSED TO AN EXPERIMENTALLY DEVELOPED PROGRAM OF MOTOR ACTIVITIES AS PART OF A PHYSICAL EDUCATION CURRICULUM DESIGNED TO CHALLENGE A CHILD. PERFORMANCE MEASURES IN THE STANDING BROAD JUMP, THE 30-YARD DASH, THE OVER ARM THROW, THE PULL-UP, AND SHUTTLE RUN WERE TAKEN AT THE BEGINNING OF THE STUDY AND AT THE END OF THE FIRST AND SECOND YEAR. SINCE MEAN COORDINATION MEASURES FROM 6 TO 12 YEARS OF AGE DIFFERED ONLY SLIGHTLY, IMPROVEMENT IN THE MEAN SCORES FOR THE RUN AND JUMP IN THESE YEARS CAN BE ATTRIBUTED IN LARGE DEGREE TO SKELETAL GROWTH, AND THE SLIGHT COORDINATION CHANGES WHICH OCCURRED MAY BE DUE TO PRACTICE RATHER THAN TO AN AGE MATURATION FACTOR. SPECIFIC MUSCLE GROUPS CAN BE STRENGTHENED, BETWEEN 6 AND 12 YEARS, THROUGH PARTICIPATION IN A SCHOOL PHYSICAL EDUCATION PROGRAM AND GAINS ARE GREATER WHEN EFFORTS ARE MADE TO STRESS VIGOROUS ACTIVITY. (JL)

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IMPROVEMENT OF MOTOR DEVELOPMENT AND PHYSICAL FITNESS in ELEMENTARY SCHOOL CHILDREN

Cooperative Research Project No. 696

by

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Chapter I. The Problem and Related Literature

I. The Problem

In the five years preceding this study, the investigators had collected data related to the motor performance and motor development of elementary school children. These observations are unique in three aspects. First, they were longitudinal; second, yearly filming of selected subjects while running, throwing and jumping provided a means of studying the process as well as the product of these basic skills; third, study of the relationship of strength to the product and the process of the three basic skills was possible by annual measures of strength of eight muscle groups selected for their relationship to the skills.

During these five years, the investigators were concerned with observations only; they did not participate in the planning nor the administration of the physical education program. With this background of data and with the conviction that the elementary school program could and should be more vigorous than it usually is, that it should be child centered rather than game centered, this two year study was initiated. In this study, in addition to collecting the same data as in the previous five years, the investigators participated in the planning and the administration of the physical education program for grades one through six. The outcomes of these two years could then be compared to those of the previous observations.

II. The Objectives

In general, the objective of this study is twofold: (1) to compare outcomes of a program of physical education of vigorous activity with those of a traditional type of program and (2) to investigate the coordinations of children Grades I through VI in fundamental skills. Specifically, the outcomes which will be compared are:

1. achievement scores in the run, jump and throw;
2. nationally recommended Physical Fitness measures;
3. strength measures of eight muscle groups.

The coordinations to be investigated will be those of the run, the standing broad jump and the overhand throw.

III. Related Research

Research related to the run, jump and throw will be presented under five classifications: the appearance of these patterns, measures of achievement in these skills, coordination in the run, jump and throw, effects of practice and instruction in these skills, and measures of strength of individual muscles and their relationship to skill.

A. Appearance of Motor Patterns

1. In infancy

Motor behavior of infants has long been intensively studied and in 1935 Bayley (2) summarized the works of Baldwin and Stecher, Ozeretsky and Shirley. From these she prepared a scale indicating the age range in which certain movements and skills normally appear. In this scale of 76 items, 80 percent are related to locomotion and patterns which are preparatory to such skill. These include progression to standing, such as ability to lift the head, to sit alone, to stand while holding to a support; progression to walking, such as alternate crawling movements with the legs while prone, stepping movements when held erect; jumping progression, such as jumping off a low box and jumping from the floor. The latter appears at 24 to 29 months and with increasing age, the distance jumped increases from approximately 4 to 12 inches at three years to 24 to 34 inches at four years. Bayley's scale does not include the run nor the throw.

Soon after the child is confident in walking, he makes run-like movements, but the rear foot does not leave the floor until the forward foot makes contact. This distinguishing feature of the run appears, according to Gesell, (13) two or three months before the second year. In observing a boy aged 14 months, Clouse (5) found that the no contact phase occurred occasionally at 20 months and that at 21 months it was a consistent part of the running pattern.

While in the first year of life "the apparently helpless bit of humanity has matched his immature powers against the great and universal force of gravity and has come through victoriously" (33), and thus achieved the ability to stand and walk, control of the upper limb has also progressed. Many children at six months of age can throw from a sitting position. (14) Though the sampling is limited, films taken at the University of Wisconsin show that at 33 months a boy had the overarm, underarm and side arm patterns. The overarm pattern, considered the most difficult, has the joint actions of the skilled mature throw. (6 - p.194) A boy, age 10 months, had the basic movement of the overarm throw - flexed forearm on abducted upper arm with medial rotation of the humerous - but preferred to carry the ball to a designated target rather than to throw it.

2. During early childhood

The most extensive study of the skills of early childhood is that reported by Gutteridge. (17) A total of 1973 children, age three to seven years, were observed by 13 teachers in nursery schools and kindergartens in 14 states. Among the 10 activities which were rated are throwing and jumping; running was not included. Jumping was defined as "launching the body from one solid surface to another - with both feet off the ground at once" and throwing as "launching the ball by a quick movement of the hand or hands and a release of the ball". The performances were rated as: no attempt made, the habit in the process of formation, and basic movement achieved. The last was further defined as showing coordinated movements, easy performance with display of satisfaction and evidence of accuracy, poise and grace. For the two observed skills of interest to this study, Gutteridge reports that at three years, 42 percent of the children were jumping well; at five years, 81 percent were skillful; in throwing, 20 percent were throwing well at four years and many were practicing and from 5.5 to six years 86 percent were proficient.

The Wisconsin films also show that in the limited sample of preschool boys, ages three to six, all could throw, using sidearm, underarm, and overarm patterns.

These observations of motor behavior during infancy and early childhood show that by three years of age the child has the basic coordinations of the run, jump and throw. It is logical that investigations beyond this age should be directed to the product and the process of performance, to measures of outcomes and of coordination.

B. Measures of Motor Achievement

The commonly used measures of performance are:
for the run, the number of seconds in which a specified distance is run with the time taken from the starting signal to the time of crossing the finish line;

for the jump, the distance in feet or inches measured from a take-off line to the point of landing of the heels or that part of the foot which first touches the ground;

for the throw, the distance in feet between a starting line and the point where the projectile first touches the ground. In some studies a target is used to measure accuracy, but since this investigation is concerned with the power of the throw, accuracy measures will not be reviewed.

Published measures of the run, jump and throw for children under 10 years of age are limited in the number of subjects and are limited to one school or locality. In the studies of this age group, summarized by Glassow and Kruse in 1960 (16), one includes records for five years of age, three for six and for seven years, and two for eight and for nine years. For age ten years and older, many studies are available. Many of these are also limited in number of subjects and in locality. Two reports are exceptions to these limitations. The first, published in 1934, presents achievement scales in 33 skills for boys and 31 skills for girls based on measures of 79,000 California children. Among the skills are ball throw for distance and run for both sexes and the standing broad jump for boys only. (34) A more recent report, 1958, includes achievement scales for seven skills, among which are the run, throw and jump for both sexes based on a nationwide sampling of 8500 boys and girls. "It should be looked upon as an initial study which gives some indication of what American youth can do in selected physical performance tests". (23)

In both reports, the achievement scales are based on a classification which considers age, height and weight. The 1958 report also includes scales for age alone. According to Espenschade, "The use of age alone as a basis for the development of test norms is recommended. Although a combination of age, height and weight has a somewhat higher predictive value than age alone in a few tests at several age levels for boys, the amount of improvement is not sufficient to justify the labor involved". (9)

A third report is of interest. This presents the average scores for the run, throw and jump for both sexes for ages 5 through 17 years for boys and through 16 years for girls. These were calculated by Espenschade from reports published in the years from 1924 to 1954. In all events and at all ages, boys' records are superior to those of girls; the greatest difference is in the throw for distance. In the three events, boys' averages increase each year. Girls' averages are the highest at 13 years for the run and at 15 years for the jump and the throw. (26)

Boys and girls in 1958-59 were heavier and taller than were those in the same California school in 1934-35, according to Espenschade and Meleney. (10) Both boys and girls of the 50's were poorer in the run and jump than those of the 30's; but the boys of the 50's were better in the throw for distance than were the boys of the 30's.

C. Coordination in Basic Skills

Studies of coordination, the process of motor performance, are limited both in the number of reports and in the number of subjects. This can be attributed to the time required by presently recognized techniques. Details of the movements of the run, throw and jump such as speed, sequence, duration of joint actions and their interrelationships, cannot be perceived in the fraction of a second in which they occur. High speed photography can record these, but techniques for measuring actions in the photographs still need refinement.

Among the published studies of films are two in which coordinations have been subjectively analyzed. One, dealing with the development of the standing broad jump beginning with a boy aged 14 months, shows that in early childhood the arms are not used effectively; that the walking pattern of alternate lower limb action persists through late childhood in the less skilled, and that jumping develops as a phylogenetic process in which the learned aspects cannot be distinguished from the automatic neuromuscular responses. (19) The second study describes four stages in the development of the overhand throw, which progresses from antero-posterior movements at two to three years to the final stage of stepping forward with the left foot, rotating the trunk with abducted upper arm. Boys reach this final stage by six years of age; girls had not achieved it even at 12 years. (41, 42) It will be noted here that in the early stages jumping lacks effective use of the arms; throwing, effective use of the trunk rotating on the lower limb.

The types of objective measures which can be obtained from film are shown in Kinesiology by Cooper and Glassow (6 p.140-164). Joint action graphed in time depicts the contributions of each segment to the total action; these exemplify the types of measures and interpretations which must be made to further understanding of coordination.

Several unpublished masters' and doctoral theses at the University of Wisconsin and one at the University of Iowa have investigated coordination in children. Three of these studied the run; four, the jump and one, the throw.

The running studies include observations of preschool boys and of elementary school boys and girls. The runs of six preschool boys, who at the beginning of the observations ranged from 14 to 60 months in age, were photographed each month from November to June. (5) The elementary school boys, 12 in number, were photographed each year, grades two through six. They were selected on the basis of their performance scores as good or poor runners. The four elementary school girls, selected on the same basis, two good and two poor, were photographed each year, ages six through ten. (7)

Each of these investigators found changes in coordination which were identified as developmental trends, changes which were evident with increasing age in both good and poor performers. The changes in the action of the swinging limb in the preschool boys were more marked than that of the supporting limb; it increased in range and speed with age. In the elementary school age in both boys and girls, this forward swing was facilitated by greater knee flexion. In the final stage of the forward swing, the knee extends and, immediately before again contacting the ground, flexes. This phenomenon is studied in detail by Fortney (12) who shows that at this time, though the foot is moving backward with reference to the distal end of the thigh, it is moving forward in reference to a fixed point in space.

In the supporting limb, in the preschool boys, there was an increase in speed with age in the actions of the ankle, knee and hip during contact, while in the elementary school girls this increase was evident only in knee and hip. (the observation of the elementary school boys was limited to the swinging limb.)

While the poor performers show the same developmental trends as the good, the degree of achievement in each did not equal that of the good performers.

The four jumping studies are not as uniformly directed to developmental trends as are the above running studies; neither are they longitudinal observations. One is a detailed study of the joint actions in the take-off of a highly skilled 12 year old girl and is noteworthy for its indications that the main propelling muscular force in the jump is due to the extension at the knee, that ankle and hip extensions are direction factors, that shoulder flexion is concerned with the shifting of the body's center of gravity and that gravitational force contributes to the projection. (25) Two studies, while not primarily concerned with coordination differences between good and poor performers, report such differences. One shows that the skilled jumpers had greater extension in ankle, knee and hip (45); the other that the ranges of knee and hip were greater in the good performers; that the speed of knee action after the thigh passed the perpendicular was greater, and that the thighs of the good performers were closer to the horizontal at landing. (18) In noting this phenomenon, Halverson discusses its advantages such as prolonging the time of flight, the resulting shortening of the distance between the body's center of gravity and the feet, and the suggestion that reach on landing is more advantageously derived from reach with the thighs rather than with the legs. (18)

Two cross sectional studies have investigated developmental trends. One author, after studying film of 64 boys and girls, ages 4 through 12 years, concluded that the "form" of the best jumpers above five years was similar to those of the best 10 and 12 year old jumpers, differing only in the angle of take-off, which decreased with age. (45) The joint actions responsible for this difference are not identified; Wisconsin studies of film suggest that it would be due to the angle which the foot makes with the take-off surface, metatarsal-phalangeal action or to the lack of full knee extension. The second investigator studied film of 57 boys and girls, ages 6 through 12 years, and observed only the flight phases. She concluded that there was a developmental trend in the starting time of thigh and trunk flexion (both of which are the result of contraction of hip flexors) and that beginning with nine years, boys began this flexion earlier than girls. (4) This detail is related to the thigh position on landing.

The single study of the overarm throw was based on films of four girls taken first when the subjects were eight years old and taken annually for three succeeding years. On the basis of performance scores, two were good and two poor. The basic pattern was the same for all performers throughout the four years. In this pattern, the subjects all increased the range of rotation of the torso with age, with the poorest performer showing the smallest range; all tended to bring the humerus closer to the horizontal in the forward movement; and all, except the poorest, rotated the humerus laterally as the torso was rotated to the left. The exception rotated the humerus prior to the forward rotation of the torso. (39)

D. Effects of Practice and Instruction

Motor ability in the first two or three years is largely dependent on maturation. See Section A, Appearance of Motor Patterns. It would seem that practice would at least affect the degree of skill, if not the appearance, of new patterns during the early years. Yet, studies which have observed the effects of short terms of training in the early years have shown that control subjects either equalled the experimental at the end of the period or at that time, with a shorter period of practice, they equalled or exceeded the gains of the experimental group. Among these are a twin study in which, beginning at 46 weeks of age, one twin received training for six weeks in block handling and climbing. The other twin, then, in three weeks of practice gained more than the other had in six weeks. (15) The skills of a group of two year olds who were given training in climbing a ladder, buttoning exercises and the use of scissors for twelve weeks, were equalled by a group who had training in the thirteenth week only. (22) After seven weeks of training on the Porteus diamond maze, children ages 24 to 40 months scored no higher than the controls. (21)

More positive indications of the results of training were found in McGraw's study of Jimmy and Johnny. Johnny's training began at the age of 20 days and continued until he was 22 months. Training in this case did not alter the underlying course of motor development, but the trained twin developed modifications of basic coordinations, such as roller skating and climbing inclines, modifications of walking and creeping. He was also more graceful and confident in movement not only at age two but also at age six, though the training had not continued through the intervening years. (28, 29)

In the age group two to six years, the effect of training and practice on throwing and jumping has been studied. The throwing studies have included both throwing at a target and throwing for distance. With a group of 30 children ages three through six years who practiced throwing at a moving target once a week for eight weeks, the gains though greater than those of paired controls were not significant. It was observed that 88 percent of the total group of 60 children used an overhand throw and that the average scores of the younger children were lower and they made greater gains than did the older children. (20) In a twin study with children ages 4 to 4.5 years trained for 4.5 months in throwing and in rolling a ball at stationary targets, both experimental and control groups gained in skill, but the gains of the control group were smaller. (32) Six periods of instruction over a period of six weeks in throwing for distance with children ages three through seven years resulted in significant gains for the experimental group, though the controls also gained during this period. The gain in skill was attributed to change in stance resulting in greater rotation of the torso. (8)

In jumping, skill improves without instruction or planned practice, though not as much. With twins aged 4 to 4.5 years, the investigator concluded that practrice accelerated skill in jumping over a height. (32) Children, ages three through seven, gained in jumping for distance without planned practice. (8) A group of kindergarten children given five periods of instruction during two weeks gained in skill during this time as did the control group. Though the experimental gains were greater, the difference was not statistically significant. (18)

Two studies have investigated the effect of specific training on skill as compared to that of participation in games involving the skill. In throwing at a target, children in the first grade made significant gains after 26 periods of class work. The difference in gains between those receiving specific instruction in the skill and those using the skill in games was not significant, though there was a slight difference in their favor. (31) In another study of first grade children, specific instruction was given in the run, jump and throw for distance once in every two weeks during the physical education classes for a total of thirteen of such periods. The experimental group improved more than the controls in the throw and the jump, but not in the run. (40)

These studies of the effect of practice and instruction indicate that while children improve in running, jumping and throwing for distance during elementary school years, planned practice and instruction can accelerate the learning. Future research should be directed toward a comparison of the kinds of practice and the methods of instruction. If physical educators employ better methods than do classroom teachers, children taught by them should reach a higher level of skill. In comparing the performances of 5th and 6th grade children, those taught by specialists were superior in the run but not in the standing broad jump. (38)

E. Strength Relationships and Norms

1. Strength - skill relationships

Strength is logically a component of motor skill and has been identified as such by a number of investigators using the factorial analysis technique. Such studies have been reviewed by Hicks and Fleishman. (35) Relationships between general motor or athletic ability and formulae for general strength have been demonstrated by Rogers, McCloy, McCurdy and Clarke. (43) However, the relationship between specific muscle groups and specific skills has not received wide attention. One such study with college men found a significant correlation between the strength of the hip extensors and the standing broad jump. (3a)

With children, the relationship between muscle groups and skill has been investigated in a number of studies under the direction of Rarick at the University of Wisconsin. Two of the earliest studies used cross sectional data. In 100 girls, grades one through six, Barsanti found r's ranging from .505 to .708 between strengths of extensors of the ankle, knee and hip and performance scores in the run and jump. When weight was held constant, all r's were still significant, ranging from .275 to .458. When age was held constant, only the r's between the knee and hip extensors were significant, .201 to .309. (1) With strength and performance scores of 114 boys, ages 7 through 12 years, Ostrander treated each age group separately and used as the strength measure, strength score divided by weight. For the run, significant r's were found with the strength measures of ankle, knee and hip extensors at age 11. For the jump, significant r's were found at ages 8, 9 and 11 years, with knee extensor measures; and at ages 7, 8 and 11 years with hip extensor measures. (36)

In her study of second grade children, 49 boys and 39 girls, Oyster calculated zero order correlations between performance scores for the run, jump and throw and strength scores of eight muscle groups - ankle, knee and hip extensors, hip, elbow and wrist flexors, shoulder adductors and medial rotators. These ranged: for the run, boys, .17 to .37; girls, -.07 to .40; for the jump, boys, .14 to .47; for the throw, boys, .24 to .53; girls, .13 to .45. (37)

Using longitudinal data, measures of 34 boys taken in the first, third and fifth grades, Wilson found significant r's between jump scores and strength scores for the knee extensors in the third grade and for the hip extensors in the fifth grade, .347 and .317. When the strength measure, strength score divided by weight was used, r's were significant with the jump score for ankle extensors in the fifth grade, and for knee and hip extensors and hip flexors in the third and fifth grades. (44)

2. Strength norms

If there is a relationship between strength and skill, it would be of interest to physical educators to know the degree of strength which can be normally expected in children of elementary school ages. An indication of age averages was reported by Martin in 1918, who measured 21 muscle groups on the left side of the body and the corresponding groups on the right side of 128 males and 112 females, ages 5 through 18 years. Because 168 of his subjects were post infantile paralysis cases and because in the age groups older than 11 years the number of cases ranged from one to seven, the age averages cannot be accepted as norms. (27) However, certain of his findings are of interest. In groupings his subjects, 5 through 7, 8 through 12, and 13 through 18, the left side measures ranged from 49.3 to 49.7 percent of the total strength, indicating that the strength of the left and right sides are approximately equal. The percentage which the upper limbs were of the total decreased from 40.4 to 38.8 in these age groups. The measure, total strength score divided by weight, (both in pounds) was approximately 20 for boys each year from 6 to 16, while for girls, this ratio varied from 15 to 19.

No such comprehensive age strength averages have been published since 1918, but the studies directed by Rarick described in the preceding section include age averages for eight muscle groups and studies by Clarke include averages for selected ages and muscle groups. (3b and c) In a review of studies in human strength, Hunsicker and Greey report that strength of males increases rapidly from 12 to 19 years at arrate similar to that of weight; more slowly and regularly up to 30 years, after which it declines at an increasing rate up to 60 years. In females, strength increases at a more uniform rate from 9 to 19 years, more slowly up to 30, after which it declines. (24)

The one strength measure which has been repeatedly measured is grip strength. This may be because grip strength is believed to be a good indication of total strength, though this has not been substantiated for elementary school ages. The grip strength averages reported from 1892 to 1942 have been summarized and evaluated by Metheny. (30) In the two most recent studies in that review, each of which includes the ages 3 through 13, Meredith for boys, Metheny for girls, the yearly percentage gain is greatest from three to four years, 49 percent for both sexes. The second greatest gain is from four to five years, 34 percent for boys, 31 percent for girls. After that the yearly percentage gain fluctuates, for boys from 10 to 21 percent until age 17 when it drops to 8 percent. For girls, the percentage gain fluctuates from 13 to 20 percent until age 14, then drops to 9 percent and at age 18 is only between 2 and 3 percent. These rates of increase, it will be noted, do not parallel those reported by Hunsiker. (24)

F. Summary

By three years of age, maturation of the neuromuscular system has resulted in ability to run, throw and jump. These skills are fundamental to large muscle activities and, during the preschool and elementary school years, will improve. The degree of improvement, as measured by achievement scores which can be expected each year is indicated in available norms for the standing broad jump, the throw for distance, and the time required to run a specified distance.

After three years, the influence of maturation has not been identified, but practice and instruction, which includes practice, can accelerate learning. Such acceleration is due to changes in coordination and identification of these would enable those who guide practice to select details of the process of performance as teaching goals.

Subjective observation and study of photographs have identified some coordination details. In the run, with age and skill, the swinging limb increases in range and speed and the supporting limb in speed of knee and hip action. In the jump, the speed of knee action has been identified not only as a factor in coordination in the take-off phase, but its mechanical importance has been identified. A study of college age women has shown this to be the outstanding difference between high and low scoring performers. (11) Arm action in the jump apparently is a learned action rather than one which is an inherent pattern. Degree of flexion of the thighs in flight distinguishes the more highly skilled performers and results in greater distance at landing. In the throw, greater rotation of the torso which is facilitated by stepping forward with the left foot, since it develops between two and six years, could possibly be maturational development, but it requires practice as shown by the earlier development in boys and the improvement during the elementary school age span. The timing of the lateral rotation of the upper arm in relation to the trunk rotation appears to be a learned pattern. It is likely that high degrees of coordination can be developed through practice and instruction during the elementary school years; if there is an age difference in this, it remains to be shown in future studies. Even if there are no differences, performance scores will still increase with age because the bony segments will be increasing in length.

As the bony segments increase in length, muscular strength increases. Strength of specific muscle groups have been shown to be related to achievement scores, but the relationship of muscle strength to speed of joint action in complex patterns such as running, throwing and jumping has not yet been investigated. Study of this relationship is closely related to the study of coordination and as these are determined can be the basis for improvement in teaching.

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Chapter II. The Experimental Situation and Procedures

I. Introduction

In the six years preceding this project, the investigators had collected longitudinal data on children as they progressed from the first through the sixth grade. The annually collected data included performance scores for the run, jump and throw; photographic recordings of these skills, and strength and anthropometric measures. As the end of the six years of observation approached, plans were made for an additional two year project. In this a vigorous physical education program would be implemented for three groups. The primary purposes would be to compare the measures of children in the two year project with those obtained in the previous six years and with other available data and to investigate the coordinations of three basic skills.

II. The Situation

A. The School

The elementary school in which the observations were made was, in the first three years, the only school in an independent school district. In the remaining years, with annexation of the area to Madison, Wisconsin, it became a part of the public school system of that city.

The school had been selected for several reasons. It was within a 15 minute drive of the university campus; the stability of the population was promising, approximately 85 percent of the families owned their homes, there were no apartment buildings in the district; the area provided ample opportunity for challenging, unsupervised motor activities for children. The last was an important factor; the investigators were primarily interested in the degree of skill which children could achieve and assumed that a challenging environment for play in after-school and vacation hours could result in greater motor development than one in which large muscle activity would be limited mainly to the time spent in physical education classes. The homes in the district were surrounded by yards; open spaces and wooded hills were within easy walking distances; none of the roads were heavily traveled; the majority of children walked to and from school or rode bicycles.

In 1953, when the observations began, the school enrollment was approximately 350, including kindergarten and eight grades. During the following years, the district population and school enrollment increased steadily. Additional classrooms were added to the building and in the last two years, the seventh and eighth grades were moved to a junior high school and some of the homes were transferred to other school districts.

One valuable asset, not known to the investigators in the preplanning period, was the cooperation of the community and the school staff. The interest of the community in the school and its desire to offer the best possible education for its children had resulted in an excellent teaching staff and an excellent relationship between parents and teachers. A single example illustrates the attitude of the community. Often children were asked to come to school on Saturday for project observations. Frequently, family schedules were adjusted and often parents came with the children to observe the proceedings. Also on occasion, the investigators were invited to explain the project at a P.T.A. meeting and report on its progress.

B. The Physical Education Facilities

The indoor space for physical education classes was a room 58 by 33 feet with a height of 10 feet. The floor was covered with asphalt tile. This space limited the activities, especially of the older children. This room also served as the auditorium for the school.

The outdoor space was ample. It included two black-topped areas, one approximately 125 by 110 feet, the other 50 by 30 feet. There was also a grass covered area large enough for a good sized soccer field or a baseball diamond. The latter was used mainly for the four upper grades.

The equipment consisted mainly of balls, of which there was an ample supply, baseballs, soccer balls, volley balls, basketballs, and small rubber balls. There were also mats for tumbling. In the outdoor space there were a permanently fixed horizontal ladder, poles for two volleyball courts, and two backboards and baskets so spaced that they provided opportunity for shooting baskets, but not for playing the game. For the two year project, the Fred Medart Company loaned to the investigators its newly developed Phy Exerciser and Phy Educator, thus increasing the range of activities which could be provided indoors.

III. Experimental Procedures

A. An Overall View

At the beginning of the school year, 1959-60, performance scores in six motor skills were obtained for all children in the first, third and fifth grades. A physical education program, designed to provide vigorous motor activity, was carried on in these grades during this school year and in the following year when they were the second, fourth and sixth grades. At the end of the year of 1959-60 and at the end of 1960-61, performance scores in the same skills were obtained.

In addition, factors which could affect motor performance were studied more intensively in a randomly selected sample, 15 boys and 15 girls, from each grade, a total of 90 children. At the end of each of the two years, the strength of eight muscle groups of each child in the sample was measured. Also at these times, the coordination of three of the motor skills, the run, jump and throw, was recorded on film.

B. The Subjects

The subjects included all children enrolled in the specified grades at the time the observations were made. These are shown in Table I (boys) and Table II (girls).

Table I. Subjects: number and age range (boys)

	October '59		June '60		June '61	
	No.	Age range	No.	Age range	No.	Age range
Grade I	49	72 - 84	48	79 - 91		
Grade II					48	91 - 103
Grade III	22	92 - 108	23	99 - 115		
Grade IV					25	112 - 127
Grade V	20	122 - 135	23	129 - 141		
Grade VI					23	141 - 158

Table II. Subjects: number and age range (girls)

	October '59		June '60		June '61	
	No.	Age range	No.	Age range	No.	Age range
Grade I	38	72 - 85	36	79 - 92		
Grade II					33	91 - 104
Grade III	34	97 - 108	32	104 - 115		
Grade IV					32	116 - 127
Grade V	29	119 - 149	28	126 - 156		
Grave VI					22	138 - 168

C. Measures of Motor Skills

1. The run

The measure of the run differs slightly from that ordinarily used. In the outdoor space, described in II 2, a starting line was marked on the black top surface. At a distance of 35 yards, a finish line was marked; also at a distance of 5 yards from the starting line, another line was marked. The score for the run was the time from crossing the 5 yard line to that of crossing the finish line. The starting time was eliminated from the score in order to obtain a more valid score of running ability. The previous six year study had shown that the starting time in the younger children was longer than that of older children. The score for each child was the average of two trials taken on the same day.

2. The jump

The jump was also measured out of doors, if weather permitted; if the weather was inclement, indoors. In both situations, the jump was from a board, 18 inches wide and 6 feet long, covered with rubber matting. The board was raised 2 inches from the jumping surface. Landing was on a rubber mat. The distance of the jump was the distance from the edge of the take-off board to the point of landing of the heel of the foot nearest the take-off board. Each child was given four trials and his score was the average of the two best jumps.

3. The throw

The measure of the throw differed radically from the ordinarily used distance covered in the throw. The difference in measurement was chosen, as it was in the run, to obtain a more valid measure. Distance of a throw is a result of the velocity imparted to the ball and the angle at which the ball is projected. The velocity is a more valid measure of the power developed in the throwing movements.

To measure the velocity, the situation included

(1) a starting line,
(2) a canvas backdrop, 15 feet wide and 13 feet in height, marked into 6 zones, each 2 feet high, which was suspended between two poles, 50 feet from the throwing line.

The ball's flight was timed, using a stop watch which recorded to the nearest 1/100 second from the time the ball left the hand until it struck the backdrop. If the ball did not reach the canvas, the watch was stopped when the ball hit the ground.

The velocity was calculated by determining the difference in height between the start and end of flight and eliminating the effect of gravitational force. (See Cooper and Glassow, Kinesiology, pp. 263-271.)

A standard, hard 9 inch baseball was used, selected as better fitted for the hands of the younger children. Each subject had four trials and the score for the throw was the average of the best two velocities in feet per second.

4. Pull-up, sit-up and shuttle run

These were administered according to the directions given in the AAHPER Youth Fitness Manual, p. 4-9. Instead of using the modified pull-up for girls, as recommended in the manual, the pull-up for boys was used for the girls because the experience of the investigators suggested that girls in the lower grades were capable of lifting the entire body weight rather than a portion of it. It should also be noted that the manual's suggested norms begin with the fourth grade, or age 10 years. The subjects in this study include the first three grades as well as the three higher grades.

5. Reliability of run, jump, and throw scores

Reliabilities of the run, jump, and throw scores had been computed during the six year study and those for girls were reported by Glassow and Kruse, Res. Quar. 21,3: 428-430, October 1960. The reliability r's calculated by these authors include 19 for the run, 21 for the jump, and 15 for the throw and include groups from the first six grades. Thirty-one of the 55 r's are .95 or above; an additional 12 are in the range .90 to .94; eight in the .85 to .89 range and the remaining 4 are .72, .74, .76, and .78. These r's are the relationship between the two measures which are averaged for the score in the skill. If the Spearman-Brown formula is applied to predict the reliability of the average of the two best trials, all except the lowest four would be above .92 and 43 of the 55 would be above .95.

D. Strength Measures

Strength scores for eight muscle groups were obtained for the subjects in the random samples at the end of each of the two years. The muscle groups were hip flexors and extensors, knee and ankle extensors, shoulder adductors and medial rotators and wrist and elbow flexors. These had been selected as muscles which could influence running, jumping and throwing skills. The measures were obtained with the use of the cable tensiometer and administered according to the directions advised by Clarke, (A manual: cable tension strength tests. West Springfield, N.H.: Stuart E. Murphy, 1953).

E. Photographing Procedures

Film records were made of the run, the jump and the throw of the subjects in the random samples at the end of each of the two years. These were taken out-of-doors in the week following the measurement of the six motor skills and in the same interval in which the strength measures were taken.

One performance of each skill by each child was photographed in the same situations in which the skills had been previously measured. In addition to the film records, the performance scores were also recorded.

The photographic equipment included:

(1) A camera, with a 4 inch lens, carrying 16mm black and white film, set to run 64 frames per second. The camera was on a tripod and was not moved during the filming. It was set 97 feet from the run space, 65 feet from the jump area, and 50 feet from the throw.

(2) A number to identify each child. The groups were identified as four, five, or six hundred; the sex, by odd and even numbers. Thus, a boy in the first grade might be 643; a girl, 642. Third grade numbers would be 543 and 542; fifth grade, 443 and 442. In the second, fourth and sixth grades, each child retained the number used in the previous year.

(3) A clock, 22 inches in diameter, whose single hand made one revolution in three seconds. Instead of 12 numbers on the face, this clock has 10; the movement of the hand from one number to the next represents the passage of .3 seconds. Passage of time can also be measured by the number of degrees which the hand moves; each degree represents 1/120 second.

(4) The date of the filming was indicated by month and year; by numbers; 6 - 60 to represent June, 1960.

The identifying number, the clock, and the date were so placed that they appeared in all frames. Before each skill was filmed, the subject was photographed in each camera field holding a meter stick. The photographed length of the meter stick would later serve as a standard for measurements of distance and length.

The photographed run included at least four strides taken during the middle third of the 30 yards. The jump included the take-off, flight, and landing. The throw included the movements preparatory to and including release and the first part of the ball flight.

F. The Physical Education Program

1. Content

The selection of activities was based on the following criteria. They should:

(1) be vigorous, demand strength and provide organic stimulation,
(2) contribute to neuromuscular development,
(3) provide opportunity for social development,
(4) be progressive in demands within each year and between years,
(5) be suitable for available space and equipment.

The selected activities can be classified as:

(1) locomotor skills: walk, run, jump, hop, leap, skip, gallop, slide;
(2) body manipulation: bending, stretching, turning, twisting, pushing, pulling;
(3) apparatus and tumbling: balancing on various parts of the body, hanging, climbing, various forms of rolling;
(4) ball handling skills: throwing (underhand, overhand, sidearm), catching, striking (kicking, batting, volleying).

The entire program was child centered rather than game centered. Games were selected because they provided opportunity to exercise basic skills in a challenging, purposeful situation. Activities were never selected because they "led up to" or were preparatory for certain games. Circle games in which all but one or two children are relatively inactive were used sparingly. Each game was introduced only when its essential skills had been developed to the degree necessary for a satisfying, purposeful experience.

One of the major differences in content, as contrasted to much published material, is the emphasis on basic skills in the first grade. Since the child has the underlying patterns for these skills by six years of age, it was recognized that the school should provide opportunity to further develop these and variations of them and provide opportunity to use them in situations of increasing complexity.

2. Implementation

a. Instructors

There were three instructors each year teaching the experimental groups, two were members of the city's physical education staff. One of these, a man, taught the boys of the fifth grade in 1959-60 and the sixth grade in 1960-61. The other, a woman, taught the girls of those grades. In both years, the classes included all members of the fifth and sixth grades. The lower grades were taught by a woman, a member of the investigating team, who was also a graduate student at the University of Wisconsin. Unfortunately, the woman who taught in 1959-60 left to be married at the end of that year and was replaced by a fourth instructor. Both women had had two years of teaching experience.

b. Instructional procedures

Instructional procedures were guided through group and individual discussions of the four teachers with the co-investigator who was primarily responsible for the development of the program content and plans for its implementation. All instructors used traditional devides - demonstration, description, manual assistance, verbal cues, audio-visual aids - in varying combinations, each according to his preference and confidence in the use of each. Yet there was continual effort to encourage practice in specific skills in situations in which the child could immediately evaluate his performance. In developing power in the throw, a distance might be set as a goal; success makes possible reinforcement of successful patterns and failure indicates to the child a need for help. When children were motivated by a desire to improve their ability to play softball, the subgoals of ability to throw, to pitch, to run were specifically defined and practiced.

In some skills, such as tumbling, dance, apparatus events, progressive objective measurement is not as easily made. Yet here, too, self-evaluation was made. In jumping from a height, the goal might be to land on the feet and maintain balance, or to land so that the contact was barely audible.

c. Class organization

With the intent of using to the maximum the time, space and equipment, efforts were made to: have equipment readily available, so that children could move from one activity to another with a minimum expenditure of time; use the time going to and from the playground for practice of skills; provide activity for those ready for work while others were dressing or changing shoes; provide maximum opportunity for individual practice by working in small groups and by rotating groups when equipment was limited.

3. Class size and time

All classes met for a half hour period three times each week. The youngest grade came to physical education in three groups, the middle grade in two. Boys and girls worked together in the two younger grades. The oldest grade came to class in two sections, one of each sex. The numbers of pupils in class sections ranged from approximately 20 to 35.

Chapter III - Results, Conclusions, and Summaries

The several types of results in this study will be presented in four parts in this chapter. Part I will compare the run, jump and throw achievement scores of the experimental groups with comparable grade level scores previously collected in the same school. Part II will compare experimental subjects' scores in nationally recommended Physical Fitness measures with published norms. Part III will compare strength scores of the experimental groups with comparable grade level scores previously collected in the same school. Part IV will present data concerning coordinations in run, jump and throw performances of the experimental subjects.

Each part will include results and conclusions or summaries related to the data in that section. A summary of all parts will be included in Chapter V.

Chapter III - Part I. Comparisons of Run, Jump and Throw Scores

Prior to this study, the investigators had collected scores of the run, jump and throw of all children in one elementary school. These scores will be compared to those of the experimental groups as an indication of the effect of the more vigorous program. These scofes will be called the "previous" scores. It will be remembered that the experimental subjects consisted of three groups, who at the beginning of the study were in Grades I, III, and V. Performances scores for these subjects were recorded in the fall and spring of the first year and in spring of the second year when the subjects were in Grades II, IV, and and VI. In some cases, among the previous groups, there are available scores for groups recorded at parallel times, that is, scores for the same groups are available for Grade I fall and Grade II spring or for Grade V spring and Grade VI spring. Thus, comparisons will be made with previous groups (all scores available) and with parallel groups (those which are comparable in the time span to those of the experimental groups).

Administration procedures for the three skills were the same for experimental, previous and parallel groups.

A. The Run

The score for the run is the average of two scores in seconds, and is the time recorded for running 30 yards. It does not include the first five yards. The run is thus actually 35 yards; the time is that of the last 30 yards.

1. Boys' run

In Table III are shown the scores of the previous and experimental groups for Grades I through VI. As expected, in general scores improve with age. In the few instances where this is not true, it could be due to differences in the composition of the group. Since the experimental subjects comprise three groups, each of these should be inspected separately. The first experimental group improved 1.20 seconds from Grade I fall to Grade II spring. In this period, the previous group gained 0.58 seconds. The second experimental group gained 0.75 seconds from Grade III fall to Grade IV spring, while the previous group gained 0.40 seconds. The third experimental group gained 0.48 seconds, while the previous group gained .032 seconds. It will be noted that not only are the gains for all experimental groups greater, but the final spring scores are better. In Grades I and III, the beginning averages of the experimental group are not as good as previous averages; while in Grade V, the average is 0.03 seconds better.

Table III
30-yard Run Scores - Boys
Experimental and Previous Group Means in Seconds; Figures in ( ) Indicate Number of Subjects

	Sept.-Oct.		May-June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	6.23(49)	5.97(95)	5.94(48)	5.74(35)		
II					5.03(48)	5.39(31)
III	5.40(22)	5.17(61)	5.17(23)	5.24(55)		
IV					4.65(25)	4.77(77)
V	4.78(20)	4.81(30)	4.87(23)	4.81(112)		
VI					4.30(23)	4.49(131

The members in the "previous" groups vary considerably, depending upon the number of grades measured at the time. The numbers in the experimental groups vary slightly, depending upon the number of boys in the grade at the time of measuring.

In Table IV are shown the average of the experimental groups and those of parallel groups for all time spans for which parallel scores were available. The gains for the experimental groups are 1.20, 0.52, and 0.48 seconds; for the corresponding parallel groups, 0.23, 0.45, and 0.21 seconds. The experimental gains exceed the parallel by 0.97, 0.07, and 0.27 seconds and all experimental final scores are better.

Table IV
30-yard Run Scores - Boys
Experimental and Parallel Group Means in Seconds

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	6.23	0.64	49	5.91	0.53	31						
II							5.03	0.48	48	5.68	0.41	13
III	5.17	0.41	23	5.34	0.41	34						
IV							4.65	0.33	25	4.89	0.36	33
V	4.78	0.43	20	4.75	0.34	89						
VI							4.30	0.34	23	4.54	0.30	88

2. Girls' run

In Table V, the improvement in scores in the girls' run Grade I through VI is seen in both experimental and previous scores. In comparing the three experimental groups with those of the previous scores, it will be seen that the experimental gains are 1.23, 0.86, and 0.66 seconds while the corresponding previous gains are 0.66, 0.21 and 0.40 seconds. The three final experimental scores exceed those of the corresponding previous groups.

Table V
30-yard Run Scores - Girls
Experimental and Previous Groups Means in Seconds;
Figures in ( ) Indicate Number of Subjects

	Sept.-Oct.		May-June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	6.26(38)	6.32(88)	5.88(36)	5.90(27)		
II					5.03(33)	5.66(35)
III	5.44(34)	5.29(62)	5.35(32)	5.28(35)		
IV					4.58(32)	5.08(66)
V	4.98(29)	4.92(74)	4.74(28)	4.88(72)		
VI					4.32(22)	4.52(54)

Comparisons with parallel scores are shown in Table VI. The gains for the experimental groups are 1.23, 0.77, and 0.42 seconds; for the parallel groups, 0.29, 0.29, and 0.33. Again not only are the experimental gains greater, but the final scores exceed those of the parallel groups.

Table VI
30-yard Run Scores - Girls
Experimental and Parallel Group Means in Seconds

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	6.26	0.45	38	6.15	0.50	29						
II							5.03	0.40	33	5.86	0.33	16
III	5.35	0.41	32	5.38	0.48	35						
IV							4.58	0.33	32	5.09	0.32	36
V	4.74	0.28	28	4.87	0.36	38						
VI							4.32	0.29	22	4.54	0.30	37

B. The Standing Broad Jump

The jump score is the average of the two best of four trials measured in the usual manner. Scores taken out-of-doors, unless the weather did not permit.

1. Boys' jump

The averages of the experimental and previously collected scores are shown in Table VII. The gains for the three experimental groups are 9.66, 6.83 and 5.52 inches, while the corresponding previous gains are 9.82, 8.90 and 6.22 inches. The experimental group gain is greater only in the Grade I - II years and only 0.16 inches. The previous group gain exceeds by 2.07 inches in the Grade III-IV years and by 0.70 in the Grade V and VI years. Except in Grade IV, the final scores do not correspond to the gains. In Grade II, the previous average exceeds the experimental by 1.02 inches; in Grade IV by 3.89 inches, and in Grade VI, the experimental group exceeds by 0.05 inches.

Table VII
Standing Broad Jump Score - Boys
Experimental and Previous Group Means in Inches;
Figures in ( ) Indicate Number of Subjects

	Sept.-Oct.		May-June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	41.04(48)	41.90(98)	48.48(47)	45.25(34)		
II					50.70(47)	51.72(46)
III	49.57(21)	51.39(61)	54.55(22)	56.73(71)		
IV					56.40(25)	60.29(73)
V	59.76(21)	59.01(56)	59.41(22)	61.52(109)		
VI					65.28(23)	65.23(133)

Scores for parallel and experimental groups are shown in Table VIII. These confirm, in Grades II and IV, the findings found with the "previous" groups. Grade. II gains are 2.4 inches greater than those of the parallel group, while in Grade IV the parallel group gains are 1.7 inches greater than those of the experimental. In Grade VI, the experimental group gained 3.4 inches more than the parallel. Except for Grade IV, the differences in final scores are only fractions of an inch.

Table VIII
Standing Broad Jump Scores - Boys
Experimental and Parallel Group Means in Inches

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	41.0	6.0	48	43.6	6.5	30						
II							50.7	5.8	47	50.9	5.9	35
III	54.6	4.7	22	55.9	5.2	50						
IV							56.4	5.6	25	59.4	5.1	56
V	59.4	6.4	22	61.8	5.5	86						
VI							65.3	6.9	23	64.3	6.9	87

2. Girls' jump

In Table IX, where the mean scores for the experimental and previous groups are presented, it will be seen that the gain for the previous groups are 9.77, 11.10, and 8.09 inches; those for the experimental are 10.42, 10.85, and 10.09 inches. The difference in gains is 0.65 inches in favor of the experimental group in the Grade I-II years; 0.25 inches in favor of the previous group in the Grade III-IV years, and 2.00 inches in favor of the experimental group in the Grade V-VI years. The differences in final scores are 0.42 inches in favor of the experimental, 0.88 inches in favor of the previous, and 0.86 inches in favor of the previous in the respective groups.

Table IX
Standing Broad Jump Scores - Girls
Experimental and Previous Group Means in Inches;
Figures in ( ) Indicate Number of Sugjects

	Sept.-Oct.		May-June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	39.11(38)	39.34(63)	47.18(35)	- - *		
II					49.53(36)	49.11(51)
III	46.31(33)	46.94(62)	54.01(30)	54.25(73)		
IV					57.16(33)	58.04(66)
V	54.89(29)	57.75(74)	59.03(27)	60.27(56)		
VI					64.98(25)	65.84(55)

*No previous first grade groups measured in May or June.

Parallel and experimental scores are recorded in Table X. The gains in the Grade III-IV years are 1.4 inches greater in the parallel group; in the Grade V-VI years, the experimental gains are 1.2 inches greater. The latter (Grades V-VI) agree with the comparisons with the previous scores. In the final scores, those of the parallel groups are greater, 0.8 and 0.1 inches.

Table X
Standing Broad Jump Scores - Girls
Experimental and Parallel Group Means in Inches

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	No parallel scores available											
II												
III	54.0	6.6	30	53.4	5.1	51						
IV							57.2	7.5	33	58.0	4.5	49
V	59.0	7.3	27	60.3	6.2	38						
VI							65.0	7.3	25	65.1	6.9	38

C. The Overhand Throw

A standard hard baseball was used for all throws. The subject stood 50 feet from a canvas back drop and was asked to throw with greatest possible speed at the canvas. The score, in feet per second, is the average of the two best velocities for four throws. This velocity is not the horizontal distance divided by the time, but one in which gravitational force and angle of projection are considered in the calculations. (See Cooper and Glassow, Kinesiology, p. 225-231).

1. Boys' throw

Comparative means scores for experimental and previous groups will be found in Table XI. The previous group gain exceeded that of the experimental group in the Grade III-IV years by 5.65 feet per second; the experimental groups exceeded in Grade I-II years by 0.45 feet per second and in the Grade V-VI years by 1.52 feet per second. However, the final scores of the groups differ substantially only in Grade VI, where the mean of the experimental group is 3.30 feet per second greater.

Table XI
Overhand Throw Scores - Boys
Experimental and Previous Group Means in Feet per Second;
Figures in ( ) Indicate Number of Subjects

	Sept.-Oct.		May-June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	37.94(48)	38.41(59)	40.04(48)	- - *		
II					47.74(47)	47.76(3
III	52.27(22)	46.09(60)	57.73(23)	51.49(35)		
IV					57.80(25)	57.27(3
V	61.00(21)	59.74(27)	64.73(23)	63.59(39)		
VI					72.26(23)	68.96(3

* No previous first grade groups measured in May or June.

Parallel means are available for the two older groups only and are shown in Table XII. In Grades III-IV, the parallel group gained 5.7 feet per second more than the experimental, yet the final score of the experimental group exceeds by 0.5 feet per second. In Grades V-VI, the experimental group gained 2.2 feet per second more than the parallel group, and its final score is also greater by 3.3 feet per second.

Table XII
Overhand Throw Scores - Boys
Experimental and Parallel Group Means in Feet per Second

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	No parallel scores available											
II												
III	57.7	10.4	23	51.5	6.6	35						
IV							57.8	6.3	25	57.3	5.5	33
V	64.7	7.5	23	63.6	7.1	39						
VI							72.3	10.1	23	69.0	5.0	37

2. Girls' throw

Means for experimental and previous groups will be found in Table XIII. Previous group gains were greater in the two younger groups; 1.77 feet per second in Grade I-II and 1.30 feet per second in Grades III-IV. The final scores for the previous groups also exceed; 5.12 feet per second in the youngest group and 1.33 feet per second in Grade IV. In the oldest group, the experimental gain was greater by 3.70 feet, but the final score was 0.67 feet less.

Table XIII
Overhand Throw Scores - Girls
Experimental and Previous Group Means in Feet per Second;
Figures in ( ) Indicate Number of Subjects

	Sept.-Oct.		May - June		May-June	
Grade	Exper.	Prev.	Exper.	Prev.	Exper.	Prev.
I	26.08(35)	29.43(52)	30.02(37)	- - *		
II					32.00(34)	37.12(29)
III	33.39(34)	33.42(62)	37.24(33)	34.83(35)		
IV					39.12(33)	40.53(36)
V	39.53(29)	43.90(30)	45.51(27)	41.62(38)		
VI					49.71(23)	50.40(37)

* No previous first grade scores available.

In the two older groups for which parallel scores are available, the parallel groups made greater gains, 3.8 feet per second in the Grade III-IV years and 4.6 feet per second in the Grade V-VI years. The final scores for the parallel group are also greater, 1.4 feet per second in Grade IV and 0.7 feet per second in Grade V.

Table XIV
Overhand Throw Scores - Girls
Experimental and Parallel Group Means in Feet per Second

	Exper.			Parallel			Exper.			Parallel		
Grade	M	SD	N	M	SD	N	M	SD	N	M	SD	N
I	No parallel scores available											
II												
III	37.2	5.9	33	34.8	4.1	35						
IV							39.1	9.1	33	40.5	5.3	36
V	45.5	8.6	27	41.6	6.5	38						
VI							49.7	7.2	23	50.4	5.1	37

D. Conclusions

The comparison of scores of the elementary school boys and girls who participated in the vigorous physical education program shows that their running scores exceeded those of pupils previously measured in the same school. Their jumping and throwing scores are not superior. A possible explanation is that running was practiced more than it had been in previous groups. Classes were asked to run to and from the playground; running was often included when the planned lesson was completed before the class period had ended. It is easily included at such times and is vigorous. If this explanation is sound, it suggests that each special skill must be practiced if improvement is to be made.

Chapter III - Part II. Comparisons of Physical Fitness Measures

Fitness scores of the experimental group using events recommended by the American Association for Health, Physical Education Recreation, will be compared to published norms. The latter are those published in the Youth Fitness Test Manual (1958) and, since these do not include records for children under 10 years, measures compiled by Espenschade (Johnson, Warren, R. Science and Medicine of Exercise and Sports, p. 435) are included. The differences in administration will be described as the scores for each event are discussed.

A. The Run

When Espenschade compiled the available means for the run, she found that measures for the run had been obtained for different distances such as 30, 40 and 50 yards. In order to obtain a "roughly comparable" score, she computed the number of yards per second. That plan has been followed here. The scores in the Youth Fitness Manual are those for a 50 yard run. To obtain a norm comparable to Espenschade's, 50 (the number representing the distance of the run) was divided by the time score for the 50th percentile. Thus, the 50th percentile for 10 year old boys is 8.8; the number of yards per second is 50 divided by 8.8 or 5.68.

The experimental group scores as presented in Part I of this chapter were for a 30 yard run. To obtain yards per second score, each group mean was increased by one-half, thus obtaining an estimation for a 45 yard run. To this was added the time for the 5 yards which preceded the 30 yards. This time had been recorded as the run scores were collected. The total time was an estimated score for a 50 yard run, and the yards per second were calculated.

Since the Espenschade and Youth Fitness scores are for age groups, to obtain a year's difference in the experimental scores only the spring scores were used. Grade I was considered a seven year old group, Grade II, an eight year old, etc.

The yards per second as presented by Espenschade, the calculated norms from the Youth Fitness Manual and those calculated for the experimental groups are shown in Table XV. The scores differ only slightly. The seven and eight year old experimental boys' and girls' scores are slightly higher than those reported by Espenschade. The experimental boys' scores for 10, 11 and 12 years are slightly lower than those of Espenschade and than those of the national norms. The experimental scores for 10, 11, and 12 year old girls are slightly higher than those of the national norms and slightly lower than those reported by Espenschade.

Table XV - Fitness Scores - Run
in Yards per Second

	BOYS			GIRLS		
Age	Espenschade	National	Exper.	Espenschade	National	Exper.
7	4.6		4.73	4.4		4.77
8	5.1		5.28	4.6		5.27
9			5.44			5.27
10	5.9	5.68	5.67	5.8	5.49	5.78
11	6.1	5.88	5.75	6.0	5.62	5.83
12	6.3	6.25	6.09	6.1	5.74	6.06

B. The Standing Broad Jump

The reported scores for the standing broad jump are likely to differ mainly in the number of trials included in the score. The national norms are derived from the best of three trials; the experimental scores are derived from the average of the two best of four trials. Espenschade's computations were undoubtedly based on a varied number of trials; this information is not included in her report.

The mean scores for boys and girls of the experimental groups exceed those reported by Espenschade and by the national AAHPER committee for all ages except 11 years for boys where the Espenschade score is 1.6 inches higher. The amount by which the experimental scores exceed the others is considerable; as much as nine inches for 12 year old girls and in only one case is the difference less than one inch (12 year old boys compared to Espenschade). Whatever the aspect of fitness measured by the standing broad jump, in this the experimental group ranks high. See Table XVI.

Table XVI - Fitness Scores - Standing Broad Jump
in Inches

	BOYS			GIRLS		
Age	Espenschade	National	Exper.	Espenschade	National	Exper.
7	41.0		48.5	40.0		47.2
8	46.7		50.7	45.9		49.5
9	50.4		54.6	51.3		54.0
10	54.7	54.0	56.4		51.0	57.2
11	61.0	58.0	59.4	52.0	54.0	59.0
12	64.9	61.0	65.3		56.0	65.0

C. The Throw

Comparison of throwing scores will be the least accurate of the three fundamental skills. The national committee used a softball, an overhand throw, and measured the distance of the throw. The score used in determining the mean was the best of three trials. Espenschade also reports the distance of the throw and does not report the type of throw or the number of trials. She says, "size and weight of balls and measurement of records differ somewhat from study to study. Insofar as possible, comparable scores have been obtained". The experimental group used the overhand throw, a hard baseball, velocity instead of distance was measured, and the average of the two best of four trials was used as the score. To obtain a somewhat comparable distance score for this group, the distance the ball would have traveled had it been released at a 44° angle was calculated for each of the sex and age group means.

The means scores for the throw are presented in Table XVII. While the distance scores for the experimental group exceed the other two groups in all cases, these cannot be accepted as evidence of better throwing ability. The experimental groups were instructed to throw as fast as possible; the other groups were throwing as far as possible. Also in calculating possible distance, it was assumed that all experimental throws were projected at an angle of 44 degrees.

Table XVII - Fitness Scores - Throw
Distance - in Feet

	BOYS			GIRLS		
Age	Espenschade	National	Exper.	Espenschade	National	Exper.
7	42.3		53.3	25.4		31.5
8	57.4		74.0	30.0		35.4
9	66.6		105.9	38.7		47.2
10	83.0	87	107.8	47.0	41	51.6
11	95.0	99	134.7	54.0	51	68.9
12	104.0	110	167.1	61.0	60	82.3

D. Pull-ups

The report made by Espenschade does not include pull-up, sit-up or shuttle run. Comparative scores will be presented only for the norms of the Youth Fitness Test Manual. This manual does not use the same form of pull-up for girls as is used for boys. The investigators of this study assumed that if pull-up was presented to the girls of the early grades that they could equal the ability of the boys. The national committee also advises only one trial, "unless it is obvious that the pupil has not had a fair chance". In this study, all pupils were given a second trial and the score presented is the average of the two trials. Results are shown in Table XVIII.

Since pull-up information for ages 7-9 years has not been widely publicized, the table includes, in addition to the mean and number for each sex and age group, the range of scores and the number of zero scores in each classification. The superiority of neither the national nor the experimental means is evident in the table. The interesting evidence is that girls' means closely approximate that of the boys and that each group makes a gain over its own record for the preceding year. (7-8 are the same group as are 9-10 and 11-12.)

Table XVIII - Fitness Scores - Pull-ups

	BOYS					GIRLS				
Age	National	Experimental				National	Experimental			
	M	M	N	Range	No. 0's	M	M	N	Range	No. 0's
7		.92	47	0-6.5	22		.57	39	0-3	21
8		2.02	43	0-8	12	Used Modified Form	.74	35	0-3	19
9		.93	23	0-3	8		.98	31	0-6.5	16
10	1	1.53	19	0-4	6		1.32	31	0-7	17
11	1	.69	23	0-5.5	16		.46	27	0-3.5	18
12	2	1.91	23	0-9	11		1.90	21	0-11	9

E. Sit-ups

The national and experimental measures were administered in the same way, except for the upper limits. In the national norms, 10-12 years, the boys were limited to 100 sit-ups and the girls to 50. In all cases, the experimental groups exceed the corresponding national norms, and insofar as sit-ups measure fitness these children are superior to the national standard.

Table XIX - Fitness Scores - Sit-ups

	BOYS				GIRLS			
Age	National	Experimental			National	Experimental		
	Mean	Mean	Number	Range	Mean	Mean	Number	Range
7		16.6	47	0-20		15.1	35	0-20
8		57.8	41	5-157		31.9	35	6-50*
9		25.1	23	2-30*		24.3	31	5-30*
10	26	52.3	19	18-100*	19	40.6	31	3-50*
11	26	32.3	23	4-50*	20	25.6	23	0-50*
12	31	60.1	23	5-100*	20	41.0	30	0-50*

*Exercise was limited to the upper limit of the range.

F. The Shuttle Run

The Shuttle run was administered to the experimental group as the procedures are described in the Youth Fitness Test Manual. The means scores given in Table XX indicate that the average scores of both boys and girls are better than the national means except for the 11 year old boys, where they were equal. The evidence indicates that in this aspect of fitness this experimental group is slightly superior to the national sample.

Table XX - Fitness Scores - Shuttle Run in Seconds

	BOYS				GIRLS			
Age	National	Experimental			National	Experimental		
	Mean	Mean	Number	Range	Mean	Mean	Number	Range
7		14.2	46	12.2-17.4		14.3	36	12.5-17.8
8		12.3	43	11.0-15.5		12.7	33	11.4-14.0
9		12.7	23	11.2-14.5		13.2	30	11.8-15.0
10	12.1	11.8	16	11.2-13.3	12.8	11.8	31	10.8-13.3
11	11.8	11.8	23	10.4-14.4	12.5	12.1	27	10.9-13.3
12	11.4	11.1	23	10.2-12.3	12.3	11.6	20	10.3-12.5

G. Summary

Experimental group mean scores in six events which have been recommended as measures of Physical Fitness were compared to means in the Youth Fitness Manual (see p. 12 reference 23) and to available age-sex means covering publications from 1924 to 1955 (see p. 12 reference 26). These comparisons can be evaluated in general terms only since the procedures for obtaining the scores were not identical.

In three events, administrative procedures, as far as can be ascertained from the literature, were the same except for the number of trials and the number of trials used to obtain an individual's score. In these events (the standing broad jump, the shuttle run, and sit-ups), the experimental means exceeded those of the other groups, except in the score for eleven year old boys, which is exceeded by the Espenschade mean by 1.6 inches.

A fourth event, the pull-up, can be compared only for 10, 11, and 12 year old boys with the norms of the Youth Fitness Manual. Administrative procedures were the same and the means scores are approximately the same. Here it is interesting to note that this event as administered to boys is generally considered too difficult for girls. Yet in the experimental groups, the girls' pull-ups were measured by the procedures used for the boys and the means are approximately equal for the sex-age groups.

The other two events, the run and the throw, can be compared with even less confidence, since calculations were necessary to obtain like measures. In the run, since the distance varied, the scores were converted to yards per second. These means show that the experimental groups were better for ages seven and eight; no comparable scores were available for nine years; for ages ten, eleven, and twelve, the experimental means for boys are not as good as those of the other norms; for these ages, the experimental girls' means exceed those of the Youth Fitness Manual but are inferior to those compiled by Espenschade.

The throw scores for the experimental groups were measured in feet per second. To obtain comparable measures, these were converted to distance scores, assuming that the angle of projection was 44 degrees. These distance scores greatly exceed the other norms.

Chapter III, Part III - Comparisons of Strength Scores

A. Rationale of the Experimental Design

The purpose of this aspect of the investigation was to determine the influence of a two year experimental physical education program on the strength development of children in grades one thru six. The strength tests which were used have been described in an earlier chapter. As previously specified, three groups of children were involved in the experimental program, the groups being in grades 1, 3 and 5 at the time the initial strength test was given. The control subjects consisted of a random sample of children upon whom similar data had been collected some years prior to initiating the experimental program. All strength tests were administered to the experimental subjects near the end of the first and second years of the experiment. It should be pointed out that the measures on the experimental subjects were not taken until some months after the experimental program was under way. Hence, training effects which may have occurred during these months were not assessed in the analysis of the data.

In order to adjust for possible initial differences between experimental and control groups, covariance analysis was used to determine the effect of the experimental program on the strength of each of the eight muscle groups at the end of the experimental period, namely, at the time these children were finishing the 2nd, 4th, and 6th grades, respectively. Separate covariance analyses were run at each of the three grade levels for each of the eight muscle groups, thus necessitating 24 analyses in all. The covariance analyses systematically adjusted first year strength score, first year heights, and first year weights between experimental and control groups. Thus, the treatment effects could be determined unclouded by initial differences in strength, height and weight. Finally, the extent to which the treatment had differential effects on strength development in the two sexes could be ascertained by noting the treatment by sex interactions.

B. Subjects

The experimental subjects for this aspect of the investigation constituted a sample of 15 boys and 15 girls in grades one, two and three, respectively, [illegible] children in these three grades at the time the investigation was begun. The control groups included a similar number of children drawn randomly from the child population described previously. The strength testing procedures were identical for experimental and control groups. An examination of the heights and weights of the experimental and control subjects by grade and sex disclosed no material differences in these measures. Hence, there is no reason to believe that there was any bias in the assignment of subjects to their respective groups or in the testing procedures.

Due to circumstances beyond the control of the investigators, a few subjects were lost during the second year of the investigation. In those instances where one or more subjects were lost from experimental group the N's in the corresponding control group were reduced to the same number by randomly withdrawing the necessary number needed to equalize the size of the two groups. Although the N's in the experimental and control groups were reduced somewhat below the original 15 subjects, there is no reason to believe that this loss introduced any systematic bias in the samples. The number of subjects in each group by sex and grade are given in Table XXI

Table XXI
Subjects in the Strength Study: Number by Sex and Grade

	Boys		Girls	
Grade	Experimental	Control	Experimental	Control
1 - 2	14	14	13	13
3 - 4	11	11	13	13
5 - 6	15	15	13	13

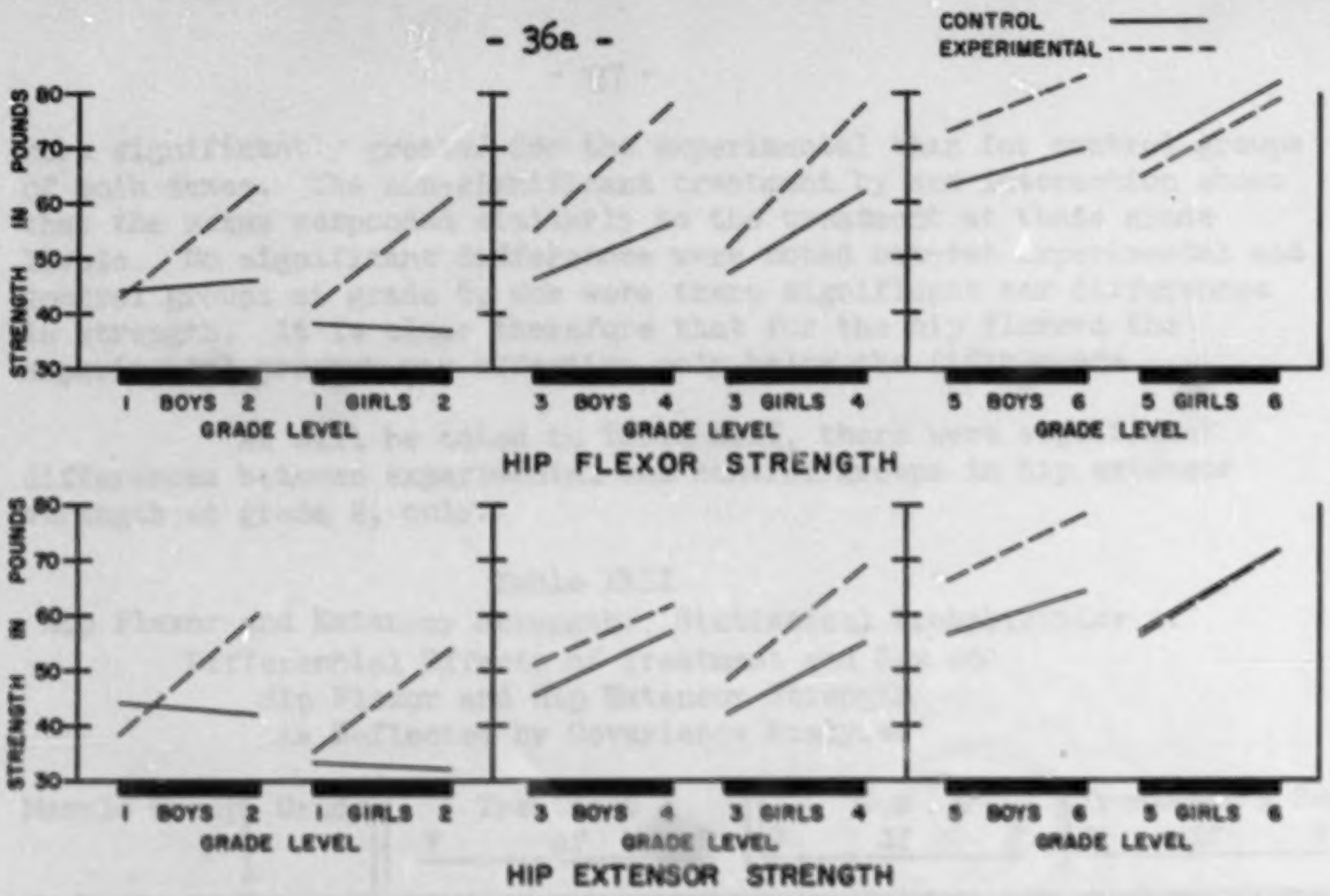
C. Findings

The presentation of the findings will be restricted to a graphic presentation of the initial and final strength means for control and experimental groups and to a summary of the results of the several covariance analyses. Since the covariance analysis made adjustments for initial differences between experimental and control groups on factors known to be related to strength, such as weight and heights, and since the analysis also adjusted for initial differences in strength, it would seem safe to conclude that any significant differences in final strength would logically be attributed to differences in treatment (the experimental program).

1. Hip Flexor and Hip Extensor Strength

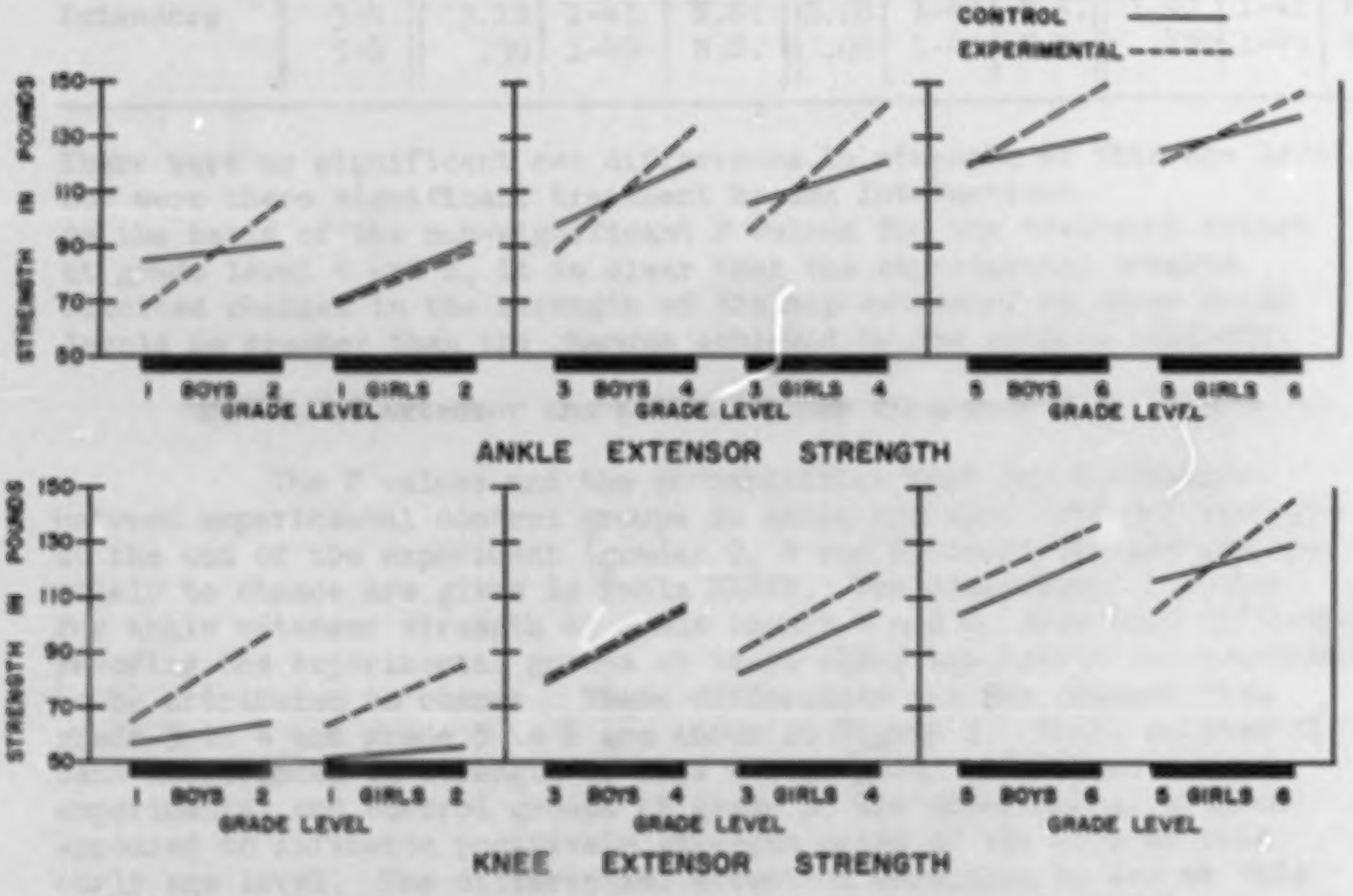
Means of the first and second year strength scores of the hip flexors and hip extensors are graphically present in Figure 1. As would be expected, the mean values for both sexes show an overall increase with advancing grade level. By visual inspection it is clear that the strength gains from grade 1 to grade 2 of the experimental subjects, both boys and girls are substantial, whereas the control groups of this age level appear to be losing ground. The means of both experimental and control groups from grades 3 to 4 show a substantial increase, although the slope of the curve of the hip flexors of the experimental groups for both sexes is steeper than that of the controls. The slope of the curves of experimental and control groups of both sexes from grades 5 to 6 is highly similar. It is clear that both experimental and control groups of both sexes at this grade level made substantial gains in strength, although the difference in incremental gains between experimentals and controls is not marked.

The probabilities that the differences in the strength of hip flexor at the end of the second year may be attributed to factors other than chance as reflected by covariance analysis are shown in Table XXII. It will be noted that the strength of the hip flexors at the end of the second year for the subjects in grades 2 and 4, respectively,



MEAN STRENGTH OF HIP FLEXORS AND EXTENSORS OF EXPERIMENTAL AND CONTROL SUBJECTS

FIGURE I



MEAN STRENGTH OF ANKLE AND KNEE EXTENSORS OF EXPERIMENTAL AND CONTROL SUBJECTS

FIGURE 2

were significantly greater for the experimental than for control groups of both sexes. The non-significant treatment by sex interaction shows that the sexes responded similarly to the treatment at these grade levels. No significant differences were noted between experimental and control groups at grade 6, nor were there significant sex differences in strength. It is clear therefore that for the hip flexors the experimental program was effective only below the fifth grade.

As will be noted in Table XXII, there were significant differences between experimental and control groups in hip extensor strength at grade 2, only.

Table XXII

Hip Flexor and Extensor Strength: Statistical Probabilities of Differential Effects of Treatment and Sex on Hip Flexor and Hip Extensor Strength As Reflected by Covariance Analyses

Muscle Group	Grade	Treatment			Sex			Treatment x Sex		
		F	df	P	F	df	P	F	df	P
Hip Flexors	1-2	62.50	1-47	.001	3.07	1-47	N.S.	1.82	1-47	N.S.
	3-4	25.06	1-41	.001	1.63	1-41	N.S.	.04	1-41	N.S.
	5-6	.01	1-49	N.S.	2.24	1-49	N.S.	.001	1-49	N.S.
Hip Extensors	1-2	45.10	1-47	.001	3.47	1-47	N.S.	.016	1-47	N.S.
	3-4	3.12	1-41	N.S.	2.28	1-47	N.S.	1.92	1-41	N.S.
	5-6	.39	1-49	N.S.	.08	1-49	N.S.	.422	1-49	N.S.

There were no significant sex differences in strength at this age level, nor were there significant treatment by sex interactions.
On the basis of the non-significant F values for the treatment effect at grade level 4 and 6, it is clear that the experimental program elicited changes in the strength of the hip extensors at these grade levels no greater than the changes achieved by the control subjects.

2. Ankle Extensor and Knee Extensor Strength

The F values and the probabilities that the differences between experimental control groups in ankle and knee extensor strength at the end of the experiment (grades 2, 4 and 6, respectively) are due solely to chance are given in Table XXIII. The significant F ratios for ankle extensor strength at grade levels 4 and 6 show that difference favoring the experimental groups at these older age levels are too great to be attributed to chance. These differences and the changes from grade 3 to 4 and grade 5 to 6 are shown in Figure 2. While no significant differences in strength of this muscle group were found between experimental and control groups at grade 2, the experimental program appeared to influence positively strength gains of the boys at this early age level. The differential effect of treatment by sex at this age level is suggested by the F value of 3.87 which approaches the F value of 4.05 necessary for significance at the .05 level.

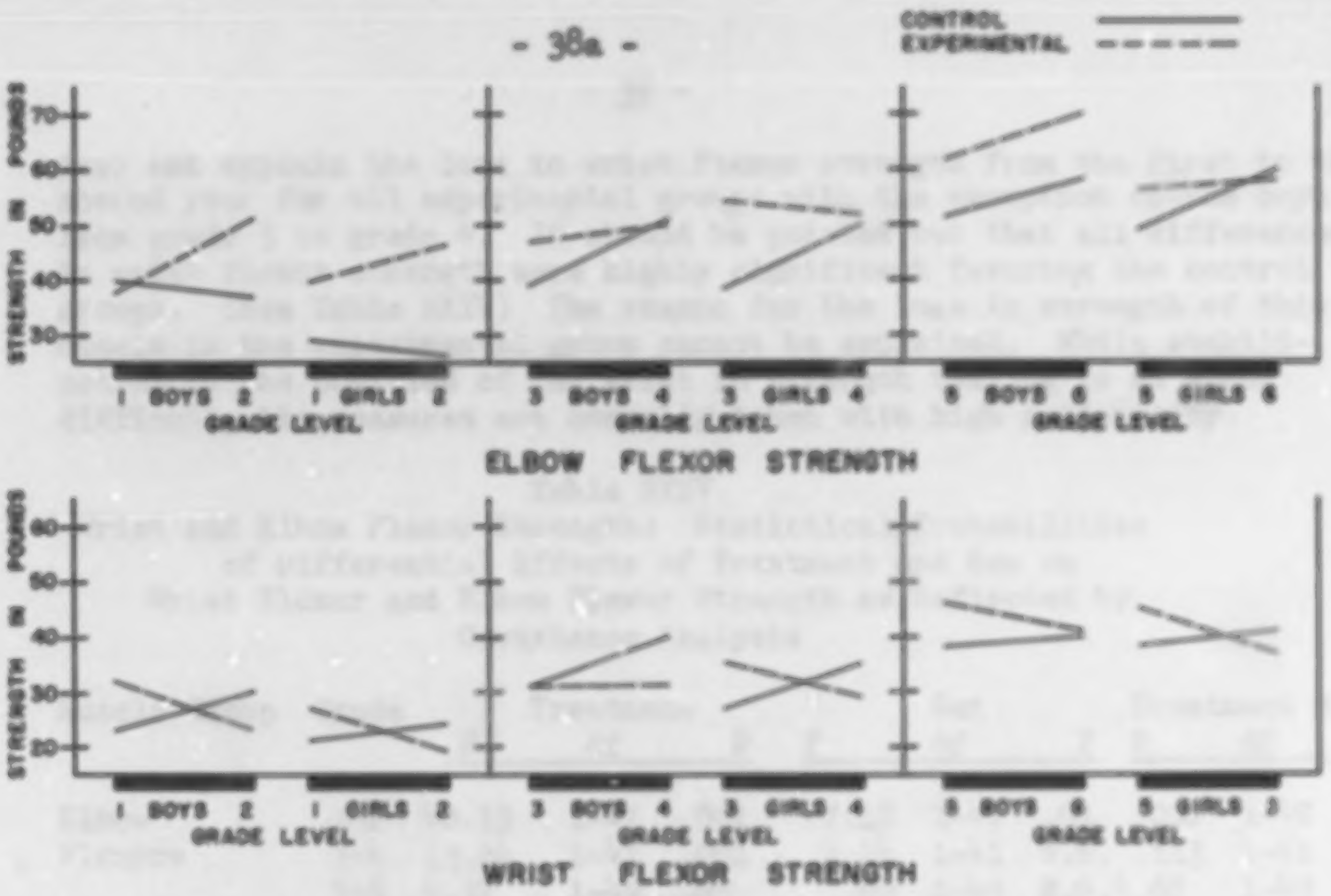
Table XXIII
Ankle and Knee Extensor Strength: Statistical Probabilities of Differential Effects of Treatment and Sex on Ankle and Knee Extensor Strength as Reflected by Covariance Analysis

Muscle Group	Grade	Treatment			Sex			Treatment x Sex		
		F	df	P	F	df	P	F	df	P
Ankle Extensors	1-2	.521	1-47	N.S.	2.04	1-47	N.S.	3.87	1-47	N.S.
	3-4	33.43	1-41	.001	.33	1-41	N.S.	.79	1-41	N.S.
	5-6	6.35	1-49	.05	.14	1-49	N.S.	.25	1-49	N.S.
Knee Extensors	1-2	40.10	1-47	.001	3.55	1-47	N.S.	.46	1-47	N.S.
	3-4	.28	1-41	N.S.	.07	1-41	N.S.	.44	1-41	N.S.
	5-6	3.71	1-49	N.S.	.06	1-49	N.S.	3.68	1-49	N.S.

In the case of the knee extensors significant differences attributable to the experimental program are seen only in the differences at the second grade level, the differences between experimental and control groups being significant at the .001 levels. These differences are graphically illustrated in Figure 2 and clearly show the substantially greater gains from grade 1 to grade 2 for the experimental groups of both sexes. The slope of the curves for the experimental and control groups of both sexes from grade 3 to grade 4 are quite similar, indicating no treatment effect. Similar trends may be noted for the boys' strength values from grade 5 to grade 6. The gain at this age level for the experimental girls is considerably greater than that of the controls and although the interaction of treatment by sex is not statistically significant, the F value of 3.68 approximates the value of 4.05 needed for the .05 level of significance.

3. Wrist Flexor and Elbow Flexor Strength

Mean differences in wrist flexor and elbow flexor strength of experimental and control groups by sex and grade level are given in Figure 3. While the overall trend in both groups for both sexes shows an increase in strength with advancing age, the apparent impact of the training program as reflected in strength changes by grade level and sex is far from consistent. It is difficult to attach meaning to the data as graphically portrayed here, although the results of the covariance analysis does prove helpful (see Table XXIV). By cross checking the probability values in the table with the plotted means in Figure 3, it will be noted that in several instances significant differences in the means at the end of the second year are higher for the control than for the experimental groups. In interpreting these results, it should be kept in mind that covariance analysis adjusts for differences in first year scores and since the experimental program had been in progress several months before the first year scores were taken, it is not surprising that in most instances the means of the first year scorer are substantially higher than those of the control groups. It is well known that it is more difficult to elicit gains in strength in those who are nearer to their physiological maximum than in those who are relatively low in strength. While this explanation may account for a few of the inconsistencies in the findings for these muscle groups, it

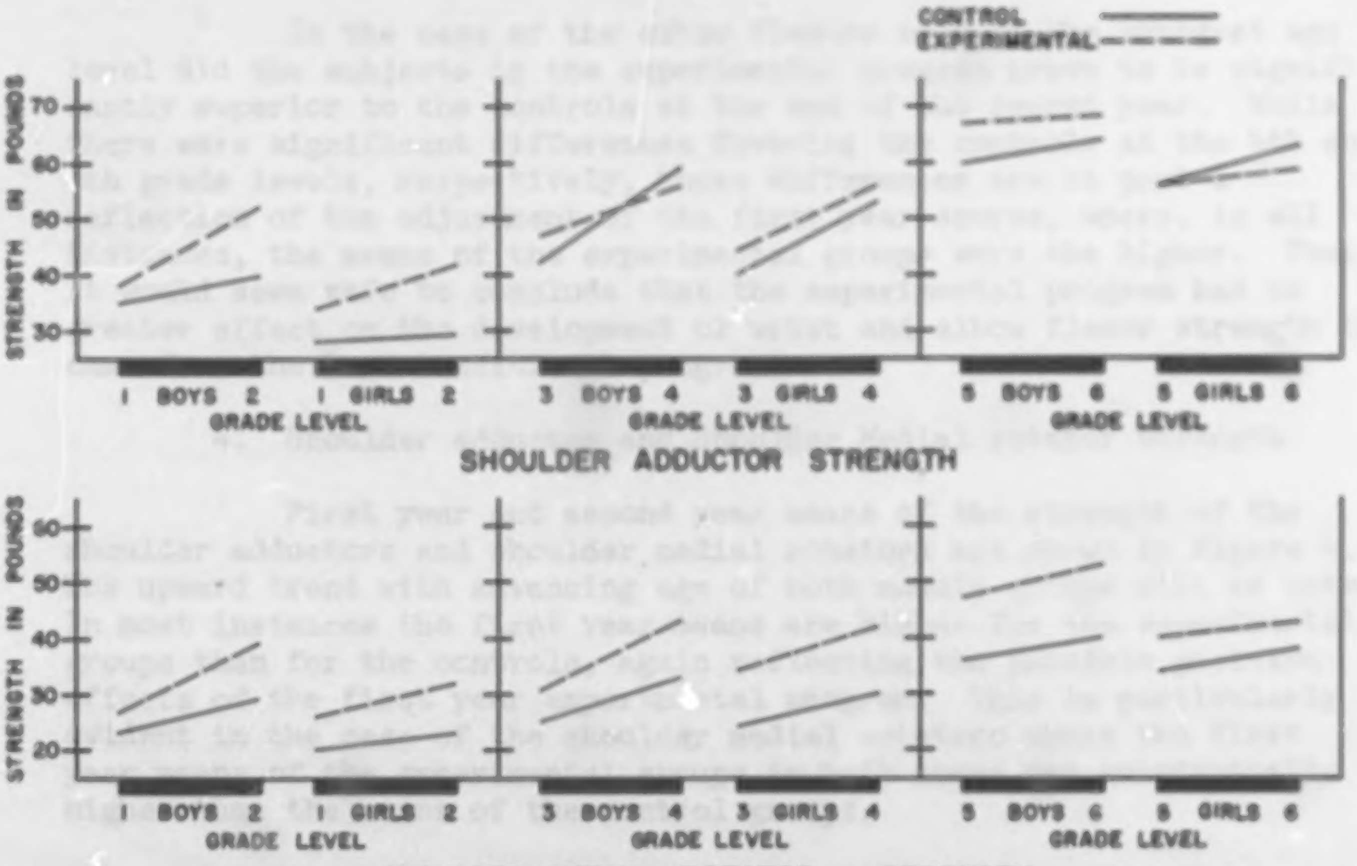


ELBOW FLEXOR STRENGTH

WRIST FLEXOR STRENGTH

MEAN STRENGTH OF ELBOW AND WRIST FLEXORS OF EXPERIMENTAL AND CONTROL SUBJECTS

FIGURE 3



SHOULDER ADDUCTOR STRENGTH

SHOULDER MEDIAL ROTATOR STRENGTH

MEAN STRENGTH OF SHOULDER ADDUCTORS AND SHOULDER MEDIAL ROTATORS OF EXPERIMENTAL AND CONTROL SUBJECTS

FIGURE 4

does not explain the loss in wrist flexor strength from the first to the second year for all experimental groups with the exception of the boys from grade 3 to grade 4. It should be pointed out that all differences in wrist flexor strength were highly significant favoring the control groups. (See Table XXIV) The reason for the loss in strength of this muscle in the experimental group cannot be explained. While stabilization of the position of the wrist in strength testing is at times difficult, the measures are normally taken with high reliability.

Table XXIV
Wrist and Elbow Flexor Strength: Statistical Probabilities
of Differential Effects of Treatment and Sex on
Wrist Flexor and Elbow Flexor Strength as Reflected by
Covariance Analysis

Muscle Group	Grade	Treatment			Sex			Treatment x Sex		
		F	df	P	F	df	P	F	df	P
Elbow Flexors	1-2	40.19	1-47	.001	7.18	1-47	.01	.001	1-47	N.S.
	3-4	13.84	1-41	.001	1.24	1-41	N.S.	.113	1-41	N.S.
	5-6	4.37	1-49	.05	.69	1-49	N.S.	4.67	1-49	.05
Wrist Flexors	1-2	15.15	1-47	.001	8.84	1-47	.01	.47	1-47	N.S.
	3-4	54.54	1-47	.001	7.57	1-41	.01	1.52	1-41	N.S.
	5-6	21.65	1-49	.001	1.23	1-49	N.S.	.84	1-47	N.S.

In the case of the elbow flexors only at the youngest age level did the subjects in the experimental program prove to be significantly superior to the controls at the end of the second year. While there were significant differences favoring the controls at the 4th and 6th grade levels, respectively, these differences are in part a reflection of the adjustment of the first year scores, where, in all instances, the means of the experimental groups were the higher. Thus, it would seem safe to conclude that the experimental program had no greater effect on the development of wrist and elbow flexor strength than came from the more traditional program.

4. Shoulder adductor and Shoulder Medial rotator Strength

First year and second year means of the strength of the shoulder adductors and shoulder medial rotators are shown in Figure 4. The upward trend with advancing age of both muscle groups will be noted. In most instances the first year means are higher for the experimental groups than for the controls, again reflecting the possible positive effects of the first year experimental program. This is particularly evident in the case of the shoulder medial rotators where the first year means of the experimental groups in both sexes are substantially higher than the means of the control groups.

The probability values for differences according to treatment and sex are given in Table XXV. For the shoulder adductors the covariance analyses showed significant treatment effects only for the scores at grade 2. While there were significant sex differences in strength (P = .01) at this grade level, favoring the boys, the insignificant treatment by sex interaction indicates there was no differential effect of the training program on the strength of this muscle group. At neither of the other two grade levels were these significant treatment effects.

Significant treatment effects were found for shoulder medial rotator strength at grades 2 and 4 (P = .01). Similarly, significant sex differences in the strength of this muscle group, favoring the boys, were noted. However, the treatment by sex interactions were not significant, indicating that there was no differential effect of the training programs for the two sexes on the strength of the shoulder medial rotators.

At grade 6 there was no significant effect of either treatment or sex. Thus, at the older age level the experimental program was in no sense superior to the more traditional program in the development of strength of either the shoulder adductors or shoulder medial rotators.

Table XXV
Shoulder Adductor and Medial Rotator Strength: Statistical Probabilities of Differential Effects of Treatment and Sex on Shoulder Adductor and Shoulder Medial Rotator Strength as Reflected by Covariance Analyses

Muscle Group	Grade	Treatment			Sex			Treatment x Sex		
		F	df	P	F	df	P	F	df	P
Shoulder Adductors	1-2	16.48	1-47	.001	8.22	1-47	.01	.067	1-47	N.S.
	3-4	3.79	1-41	N.S.	.13	1-41	N.S.	2.510	1-41	N.S.
	5-6	1.96	1-49	N.S.	.32	1-49	N.S.	.07	1-49	N.S.
Shoulder Medial Rotators	1-2	11.11	1-47	.01	5.77	1-47	.05	.09	1-47	N.S.
	3-4	11.71	1-41	.01	6.53	1-41	.05	.02	1-41	N.S.
	5-6	.51	1-49	N.S.	1.89	1-49	N.S.	.53	1-49	N.S.

D. Summary of Findings

In summarizing the findings, attention is first directed to the fact that the initial strength testing was done near the end of the first year of the study, some eight months after the experimental program was begun. Thus, any early gains in strength which were made by the experimental subjects are not reflected in the covariance analysis.

The positive effect of the experimental program on the development of the strength of the four muscle groups of the lower extremities is clearly evident. Of the 24 observations by grade and sex (6 observations for each of 4 muscle groups) only in two instances were the means of the control superior to the means of the experimental groups at the end of the second year. Six of the 12 F ratios from the covariance analyses favored the experimental groups. None of the treatment by sex interactions were significant, which indicates clearly that the training program did not differentially affect strength development in the two sexes. It is apparent that the experimental program relative to developing strength in the lower extremities was most effective at the younger age levels for significant treatment effects occurred consistently more often here than at the older age levels.

The effects of the experimental program on the strength of the upper extremity muscle groups is less clearly defined. The strength of the wrist flexors in particular responded in an unpredictable way. In five of the six experimental groups there was a loss in mean strength from initial to final testing, whereas all six control groups showed small to sizeable gains. The differences between experimental and control groups were highly significant, all favoring the controls. However, five of the six means for the measure at initial testing favored the experimental groups. Apparently some unidentified factor was systematically operating at the time the final measures were taken or during the second year of the study to produce these differences. The former explanation would seem the more plausible, since this type of response was noted only in this muscle group.

While there were significant differences in strength of the elbow flexors between experimental and control groups at the end of the training period, only the differences at grade two favored the experimental groups. However, at the two elder age levels the differences in the strength of this muscle group at the time of initial testing were substantially higher for the experimental than the control groups of both sexes, thus reflecting possible effects of the early training. This, however, does not explain the fact that three of the six control groups approximated or exceeded the means of the experimental groups at the time of final testing.

Significant differences in strength at the end of the experimental period were found for the shoulder adductors at grade two and for the shoulder medial rotators at grades two and four. It should be mentioned that the mean strength of these muscle groups in the experimental subjects exceeded the means of the controls at initial testing in 11 of the 12 instances, thus reflecting the possible influence of the early training. While the effects of the two experimental programs on the strength development of these muscle groups is not clearly established by the data, the general trend favors the experimental groups.

In summary, the findings of this aspect of the investigating indicates that the rigorous experimental program did in general bring about changes in muscular strength superior to the results achieved from the more traditional program. The superiority is clearly evident for muscle groups of the lower extremities, less clearly defined for the upper extremities. Generally, the younger children elicited greater gains from the experimental program than the older children. No differential effects of the training program on strength development were noted for the two sexes.

As a guide to the future, it is recommended that, if greater strength of the musculature of the upper extremities is desirable, future programs must provide activities which will place considerable physical stress on the shoulder girdle musculature. While it is believed that the experimental program employed here did attempt to give consideration to this need, it apparently fell short in this respect. However, the gains achieved in the strength of the lower extremities clearly show that physical education programs in the school setting, if well planned, can bring about noteworthy gains in muscular strength.

Chapter III - Part IV Coordination Measures of the Run, Jump, and Throw

A. Introduction

It is commonly known that group performance scores for boys' and girls' runs, jumps, and throws improve with age from 6 through 12 years. Yet little explanation for this improvement is available. This study attempts to find such explanation. For this purpose, action pictures were taken of the running, jumping, and throwing performances of randomly selected subjects, 15 boys and 15 girls from each of Grades I, III, and V at the end of the school year. These subjects were photographed again at the end of the next school year when they were in Grades II, IV, and VI. Some children had left the school during this time and the numbers in the second year were in Grade II, 14 boys and 13 girls; in Grade IV, 11 boys and 12 girls; in Grade VI, 14 boys and 12 girls.

The film was studied by projecting it on a film reader (recordak, from Recordak Corporation, 847 West Jackson Boulevard, Chicago, Illinois). Two types of these readers were used; one magnified the 16mm film 20 times; the other 40 times. When linear measures were desired, the projected length was measured to the nearest 1/30 inch, which was then translated to actual measure by a proportion related to a yard stick which was photographed in the field of action preceding each individual performance.

Angles between body segments were determined from line tracings of body segments in selected frames. The investigator subjectively chose the line which represented the position of the segment in space and then, with care that the tracing paper was in the same position in relation to the film frame under observation, added lines to represent other desired segments. The tracings are thus straight lines not outlines of body contours.

A frame by frame analysis of the photographed groups was an impossible task from the standpoint of time. In each activity, key frames were selected for study; these will be described under each skill.

B. Procedures for Identifying Age Trends

The problem to be investigated in this aspect of the study is the identification of coordination measures which are related to performance scores in the run, jump, and throw which change with age. Data was obtained from film showing the running, jumping, and throwing actions of each subject at the time his performance score was recorded. Some selected measure thought to be related to the performance score was inspected for the type of zero order r, positive or negative, between the measure and the performance score. If the r's were predominantly positive or negative for all age and sex groups, this was accepted as evidence of relationship. For example, the length of stride is thought to be related to the speed of the run. Inspection of the r's between these two measures show that of 24 such calculated relationships, 21 were negative. This was accepted as proof that in each age and sex group, the longer the stride, the better (lower in seconds) the running score.

To determine whether the stride length increases with age, the means of the lengths were inspected.

Next measures which might affect stride length were inspected for their relationship to that length. If found to be predominantly of one type, those means were inspected for age trends.

C. The Run

1. Achievement scores

The mean of the running measures of the photographed group are presented in Table XXVI. All are derived from the time in which each individual ran 30 yards, excluding the first 5 yards of a 35 yard run. The means in the Film column are those of a single trial in which the mid phase was photographed. Those in the Performance column are the means of individual averages of two trials taken in the week preceding the filming. The time scores were obtained by an experienced timer. The differences in Film and Performance means may be due to stop watch errors or to actual differences in performance of the subjects.

Of special interest here is the improvement in mean film scores from Grade I through Grade VI, shown in every case except for Grade VI girls.

Table XXVI
Run Scores of Photographed Subjects in Seconds

	BOYS		GIRLS	
Grade	Film	Performance	Film	Performance
I	5.84	5.74	5.90	5.84
II	5.16	4.90	5.22	5.18
III	5.15	5.13	4.86	5.21
IV	4.78	4.66	4.58	4.47
V	4.60	4.80	4.37	4.79
VI	4.36	4.26	4.67	5.22

2. Film measures

Films of motor performances provide so many possibilities for investigation that for each study some choice must be made. For this study, it was decided to study in detail the action of the lower limbs and the trunk as shown in three frames, (1) the first frame in which the foot contacted the ground, (2) that in which the lower leg reached a position perpendicular to the ground, and (3) the take-off frame, that of last contact with the ground. In each frame, nine measures were made: the angles at the ankle, knee, and hip of the supporting limb; the angles with the horizontal of foot, leg, and thigh of the supporting limb and of the trunk and the swinging thigh; the knee angle of the swinging leg. These measures were made in each of the three frames for a right and a left stride, a total of 54 measures.

From these were calculated the range of movement in degrees from leg perpendicular to take-off for ankle, knee, hip, foot, leg, thigh, trunk, swinging thigh and knee (9 measures for each stride) and the angular velocity of each of these except the swinging knee (8 measures for each stride), a total of 34 measures. Also from the film, the time during which the foot was in contact with the ground, the time from leg perpendicular to take-off, and the time the body was in flight, and the length of each stride was determined, a total of 8 measures. From the time measures, two percentages for each stride were calculated; flight time as a percentage of total time (contact plus flight) and time from leg perpendicular to take-off as a percentage of contact time, a total of four measures. These with the film time for each run add to a grand total of 101 measures. To these were added 17 other measures (age, length of body segments, strength measures) which will not be listed in detail here. This list of 117 measures was the limit which the available computer could take at one feeding. The machine calculated the means, standard deviations, and intercorrelations for 117 measures.

Of the available hundreds of calculations, only those which were found to be related to the coordination of the run will be presented in the following discussion.

3. Length of stride

A long stride has been identified as a characteristic of faster runners and for this reason the length of each individual's stride was included in the measures. This length was measured from tracings taken from the film. The frame in which the foot last contacted the ground was projected on a sheet of paper and on this was first drawn a vertical and a horizontal line showing the position of the clock which appeared in all frames. With these lines directly over the clock, a dot was placed on the paper at the front end of the foot. The film was then turned to the first frame of contact with the ground at the end of the flight phase. The paper was then adjusted to bring the horizontal and vertical lines over the clock and a second dot was placed at the point of contact. The horizontal distance between the dots was measured in fiftieths of an inch and this measure was converted to actual distance by a ratio based on the film measure of a meter stick photographed before each subject began his run. These measures were made for a right and a left stride for each subject.

The length of each stride was correlated with the time score for the film run of 30 yards. See Table XXVII.

Table XXVII - Stride Lengths in the Run
Means and Standard Deviations in Feet and r's
With Film Run Score; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-20	-43	4.18	.24
II	-62	-35	4.15	.29
III	-52	-29	4.57	.42
IV	-76	-48	4.55	.54
V	-51	-38	4.90	.32
VI	-69	-69	5.02	.38

Table XXVII cont.

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	-01	12	4.08	.31
II	-69	-61	4.03	.33
III	04	07	4.75	.34
IV	-60	-64	4.72	.43
V	-09	-59	4.95	.46
VI	-56	-47	4.87	.43

The correlations are predominantly negative, showing that within each sex and age group, except girls Grades I and III, the longer stride is related to the better time score for the run.

The means of the second year, except for Grade VI boys, are smaller than are the first year measures. However, none of these year to year measures are as much as one inch. These could be measurement errors. The means of each group exceeded those of the younger group, those of Grades III and IV are larger than those of Grades I and II; those of Grades V and VI, larger than those of Grades III and IV. These differences are all larger than one inch. The Grade VI boys exceed Grade I boys by 10.08 inches; Grade VI girls, Grade I girls by 9.48 inches.

Since the stride length is related to the speed of the run, the data was further examined to find explanation for the longer stride. The body position at landing will be examined since it is possible that the reach of the leg or thigh would lengthen the stride.

The r's between stride length and hip angle show a consistently negative correlation. When the hip is fully extended, in line with the trunk, the angle was measured as 180 degrees. As the thigh is raised, the hip angle becomes smaller and the distal end of the thigh is farther ahead and could then add to the length of the stride. See Table XXVIII.

However, the mean scores do not indicate that the older group have greater hip flexion as they contact the ground after flight. The trend, though small, is in the opposite direction. See Table XXVIII.

Table XXVIII - Hip Angle at Contact in the Run
Supporting Limb Means and Standard Deviations in Degrees;
r's with Stride Length, Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	43	-26	146	8.9
II	-25	-09	142	7.4
III	-05	-46	145	6.4
IV	-17	-28	145	7.4
V	-42	-06	147	6.4
VI	-20	-33	149	9.2

Table XXVIII cont.

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	06	-33	144	7.2
II	-38	-62	138	8.1
III	-36	-57	143	10.9
IV	-14	-49	143	6.7
V	-56	-24	149	9.4
VI	-51	-78	147	7.3

A 90 degree hip angle does not mean that the thigh is in a horizontal position, for that position is affected by the position of other supporting segments. The r's between thigh position and stride length are shown in Tables XXIX. These are predominantly positive. The inclination was measured as the angle between the line representing the thigh and a horizontal line extending forward from the knee. When the thigh line is back and is an extension of the horizontal line, the angle was measured as 180 degrees. The r's show that as the thigh approaches this extension, the stride tends to be longer, thus the r's are positive.

Table XXIX - Thigh Inclination at Contact in the Run Supporting Limb Means and Standard Deviations in degrees; r's with Stride Length; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-05	42	117	6.6
II	20	-23	119	5.0
III	04	47	117	6.3
IV	15	31	120	7.1
V	-24	-45	115	5.8
VI	+00	28	113	7.7

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	-05	20	116	4.1
II	45	61	121	5.1
III	46	35	118	8.5
IV	-26	43	119	4.2
V	52	42	112	6.4
VI	64	36	114	5.1

Though not consistent, the age trend appears to be toward less inclination and a less effective reach. See Table XXIX.

The hip joint and the thigh inclination alone cannot account for the increase in stride length. Another possible factor might be the length of the thigh which increases from year to year.

The boys' mean thigh length in Grade I is 11.3 inches; in Grade VI, 14.9 inches, an increase of 3.6 inches in length. The girls' measures are 12.6 and 15.3, an increase of 2.7 inches. The r's between stride and thigh length are predominantly positive, the longer the thigh, the longer the stride. These are shown in Table XXX. These correlations suggest that the boys make better use of thigh length than do the girls, especially the Grade II and Grade V girls.

Table XXX - Thigh Lengths
Means and Standard Deviations in Inches;
r's with Stride Length; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	14	-47	11.3	.46
II	14	60	12.3	.64
III	48	71	13.1	.71
IV	47	71	13.4	.56
V	48	25	13.6	.12
VI	64	56	14.9	.85
		GIRLS		
I	10	15	12.6	.52
II	-48	-26	13.2	.82
III	-14	10	13.6	.50
IV	-26	-08	14.0	.58
V	34	33	14.5	.85
VI	34	62	15.3	1.1

4. Contact time

Since previous studies have indicated that the contact time and the flight time of a stride are related to the speed of the run, time measures of contact and flight were obtained from the film. These measures when correlated with the film running score, show a consistent relationship with the contact but not with the flight time. The r's with contact time are shown in Table XXXI. All r's are positive, showing that the shorter the contact time, the lower (better) the running score.

Table XXXI - Contact Time in the Run
Means and Standard Deviations in Seconds;
r's with Film Run Score; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	31	29	.145	.025
II	58	58	.135	.015
III	93	77	.130	.020
IV	71	63	.135	.020
V	54	72	.125	.015
VI	31	27	.130	.020
GIRLS				
I	05	21	.140	.010
II	40	63	.140	.015
III	49	55	.135	.015
IV	25	33	.135	.015
V	24	03	.130	.010
VI	27	41	.135	.010

While the mean contact time scores do not show a decrease from year to year, the general age trend shows such decrease. None of the means are larger than 0.145 seconds and it is likely that the time measures used by the investigators were not fine enough to make accurate measures in hundredths and thousandths of a second. Time was obtained by finding the time per frame for each film and then counting the number of frames of contact. While these could be accurate, there is still the possibility that camera, running at 64 frames per second could miss the first point of contact and the point of take-off.

Since the contact time is related to the speed of the run, the position at contact was examined. The joint positions do not show a consistent relationship to the time of contact, but the position of foot, leg, and thigh do.

In Grade I the contact is made with the heel and the fore part of the foot is sloped upward, forming an angle between the foot and the ground seven degrees for boys and eight degrees for the girls. This angle decreases with age and, in the boys has a negative mean, indicating that the fore part of the foot made the first contact and the angle is then that between the rear of the foot and the ground. See Table XXXII.

Table XXXII - Foot Position at Contact in the Run
Means and Standard Deviation in Degrees
and r's with Contact Time; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	58	62	7	.085
II	11	27	4	.074
III	60	71	2	.092
IV	45	29	1	.052
V	29	23	-2	.104
VI	44	74	-1	.094

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	-47	17	8	.070
II	67	26	7	.075
III	27	12	5	.102
IV	76	40	4	.082
V	51	42	5	.100
VI	21	-01	6	.079

The inclination of the leg also shows a consistent positive relationship with contact time; the closer to 90 degrees of leg inclination, the shorter the contact time. This is mechanically advantageous. When the leg is inclined beyond 90 degrees at contact, its position leads to resist the forward movement of the body. The means indicate that there is an age trend toward the mechanically advantageous position. See Table XXXIII.

Table XXXIII - Leg Inclination at Contact in the Run
Means and Standard Deviations in Degrees and
r with Contact Time; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	52	62	98	6.2
II	38	53	97	6.3
III	50	42	94	5.0
IV	22	70	94	3.7
V	45	20	92	6.0
VI	34	63	92	5.2

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	-33	24	96	3.2
II	61	27	95	4.6
III	42	08	95	4.4
IV	49	72	94	3.8
V	57	58	92	3.4
VI	69	45	94	3.6

2

The inclination of the thigh has a positive relationship to contact time; the less the thigh is lowered to the rear, the less the contact time. The thigh, with its axis of movement at the knee, carries the body mass above that joint. If this mass is lowered less, less time and energy are needed to carry it up, over, and beyond the foot. The age trend in thigh inclination at contact favors this position rather than one which would add to the length of stride, where it was noted that the trend was opposite to that of increasing stride length. See Table XXXIV.

Table XXXIV - Thigh Inclination at Contact in the Run
Means and Standard Deviations in Degrees and
r's with Contact Time

GRADE	Stride R	L	Mean	S.D.
		BOYS		
I	32	45	117	6.6
II	-04	36	119	5.0
III	61	62	117	6.3
IV	03	66	120	7.1
V	29	11	115	5.8
VI	74	59	113	7.7
		GIRLS		
I	31	49	116	4.1
II	29	50	121	5.1
III	25	77	118	8.5
IV	19	-13	119	4.2
V	53	09	112	6.4
VI	39	-07	114	5.1

The swinging limb measures also show consistent relationships to contact time. The correlations with knee flexion show that the greater the knee flexion, the shorter the contact time. This is mechanically advantageous; greater knee flexion brings the center of gravity of the swinging limb closer to the axis at the hip joint and facilitates the swing of the limb during contact. The means show that the flexion becomes greater (smaller angle) as age increases.

Table XXXV - Knee Joint of Swinging Limb at Contact in the Run
Means and Standard Deviations in Degrees
and r's with Contact Time;
Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	76	51	76	20.5
II	24	48	74	13.7
III	49	63	76	12.2
IV	62	67	72	15.4
V	61	33	76	11.6
VI	44	82	70	13.6

GIRLS

I	64	26	82	9.6
II	58	73	78	14.6
III	09	66	73	12.7
IV	67	27	71	9.8
V	67	-21	71	15.1
VI	75	63	73	15.2

The inclination of the swinging thigh is consistently negatively related to contact time; the inclination would measure 90 degrees if the thigh were perpendicular; if it slopes backward from a horizontal through the knee, the measure is less than 90. The negative r's show that the closer to 90 degrees at contact, the shorter the contact time. As the swinging thigh approaches 90 degrees, it brings its weight closer to a position over the supporting foot and facilitates forward movement during contact. The means show an age tendency to this more advantageous position. See Table XXXVI.

Table XXXVI - Thigh Inclination of the Swinging Limb at Contact in the Run
Means and Standard Deviations in Degrees and
r's with Contact Time; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-75	-51	81	13.6
II	-01	-39	81	14.9
III	-31	-66	79	12.0
IV	-44	-76	84	10.2
V	-59	-25	84	11.7
VI	-59	-22	86	10.7

GIRLS

I	-13	-16	77	8.5
II	-28	-36	79	8.1
III	-08	-52	82	8.4
IV	27	-36	80	6.8
V	-43	-33	82	11.7
VI	-73	-33	83	7.6

5. Flight time percentage

While time of flight did not have consistent relationships to film run scores, the percentage of flight time does show a consistent negative relationship to the film run score for boys and a fairly consistent relationship for girls. Percentage was obtained by dividing the time of flight by the sum of contact and flight times. The greater the flight time percentage, the faster the run. The mean percentage scores also show an age trend; the difference between Grades I and VI is 6.4 percent for boys and 7.3 for girls. See Table XXXVII.

Table XXXVII - Flight Time Percentage in the Run
Means and Standard Deviations in Percentage and
r's with Film Run Score; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-12	-24	44.7	8.2
II	-44	-38	48.1	4.9
III	-89	-68	48.2	5.6
IV	-77	-44	50.9	5.8
V	-47	-31	50.1	4.3
VI	-19	-30	51.1	5.3

Table XXXVII - cont.

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	35	01	42.4	4.7
II	-53	-54	46.6	4.5
III	-07	-27	47.2	4.4
IV	-37	-55	49.3	4.4
V	59	20	51.8	4.0
VI	-08	-19	49.7	3.6

6. Segmental velocities at take-off

The velocity of body segments at take-off provide the propulsive force for the flight. The angular velocities of foot, leg, and thigh were obtained by measuring the angles of inclination of these segments when, during contact, the leg had reached a perpendicular position and again in the take-off frame. The difference in the two measures for each segment was divided by the time between these frames, giving the angular velocity.

The correlations of these velocities with the film run scores are consistently negative; the faster the movement of the segment, the faster the run. In foot velocity, each group has a gain in the second year, but group to group gain is not evident. See Table XXXVIII.

Table XXXVIII - Foot Velocity at Take-Off in the Run
Means and Standard Deviations in Degrees per
Second and r's with Film Run Score;
Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-50	-42	542	93
II	-68	-53	598	91
III	-41	-67	539	86
IV	-40	-64	562	97
V	-36	-60	560	104
VI	-28	-20	625	95

GIRLS

GRADE	Stride R	L	Mean	S.D.
I	-71	-49	525	68
II	-52	-26	542	50
III	-38	-13	584	64
IV	-37	-48	591	60
V	-41	-45	518	75
VI	-69	-16	534	70

In leg velocity there is no gain from year to year; nor is there a gain from group to group. See Table XXXIX. This is also true of thigh velocity for the supporting levels. See Table XL.

Table XXXIX - Leg Velocity at Take-Off in the Run
Means and Standard Deviations in Degrees per Second and
r's with Film Run Score; Decimal Points for r's Omitted

GRADE	Stride R	L	Mean	S.D.
		BOYS		
I	-33	-03	371	60
II	-42	-60	392	39
III	-40	-76	377	34
IV	-56	-62	373	40
V	-42	-27	389	52
VI	-52	-46	379	46
		GIRLS		
I	-25	-28	349	52
II	-58	-77	375	46
III	-50	-32	381	43
IV	-03	-39	367	28
V	-69	-69	367	66
VI	-45	-63	347	51

Table XL - Thigh Velocity at Take-Off in the Run
Means and Standard Deviations in Degrees per Second and
r's with Film Run Score; Decimal Points for r's Omitted

GRADE	Stride R	L	Mean	S.D.
		BOYS		
I	-33	-39	492	99
II	-58	-60	526	72
III	-46	-41	556	86
IV	-43	-48	513	78
V	-54	-44	515	99
VI	-46	03	501	45
		GIRLS		
I	-53	-27	458	66
II	-10	-67	457	57
III	46	08	478	77
IV	-55	-75	495	71
V	-24	-82	440	86
VI	-34	-52	450	52

The velocity of the swinging thigh is also consistently negatively related to the speed of the run. This action aids in carrying the body weight to a forward position and its movement increases the force of the push against the ground. There is no age trend in this velocity. See Table XLI.

Table XLI - Swinging Thigh Velocity at Take-Off in the Run
Means and Standard Deviations in Degrees per Second and
r's with Film Run Score; Decimal Points for r's Omitted

BOYS

GRADE	Stride R	L	Mean	S.D.
I	-61	-17	442	122
II	-40	-75	504	118
III	-60	07	548	97
IV	-59	-47	536	83
V	-39	-56	509	112
VI	-05	-29	542	75

GIRLS

I	-34	-42	477	102
II	-85	-68	482	101
III	17	04	474	107
IV	-40	-64	522	78
V	-69	-62	509	109
VI	-48	-28	479	92

7. Strength relationships

The strength gains have been shown in Chapter III, Part II. Also included in the measures was the strength of each joint divided by the body weight. When correlated with the velocity of the segments above it, each strength measure for the boys shows a consistent positive correlation as does the strength weight ratio. However, the correlations for the girls show a greater number of positive correlations for strength weight ratio with velocity than does the strength measure. The r's with the ratio measures were therefore chosen to be presented for both boys and girls.

Since the foot is supported on the ground, the joint movements are "reversed" muscle actions; that is, ankle extensors move the leg, knee extensors, the thigh. The foot is pulled off the ground by gravitational force after the center of gravity passes beyond the metatarsal phalangeal joints. Each moving segment must also move the segments above it, and thus the angle strength might be related to the movement of these additional segments. The ankle extensors ratio may affect or be related to the velocity of the leg, the thigh and the swinging thigh. These relationships are shown in Table XLII. There it will be seen that for boys, the ankle - strength ratio is consistently positively related to the angular velocity of the supporting leg and thigh and to the swinging thigh. The greater the strength of the ankle extensors in relation to the body weight, the greater the velocity of these segments at take-off. For the girls, the positive correlations are in the majority not as consistent.

Table XLII - Ankle Extensor Strength-Relationships
Means and Standard Deviations and r's with Leg and Thigh
Velocities of Supporting Limb and with Velocity of
Swinging Thigh; Decimal Points for r's Omitted

BOYS

	Leg Velocity		Thigh Velocity		SW Thigh Vel.		Ratio	
Grade	Stride R	L	Stride R	L	Stride R	L	Mean	S.D.
I	47	46	42	46	45	50	1.24	.22
II	27	22	17	19	61	66	1.71	.40
III	85	58	85	58	-01	65	1.35	.15
IV	52	32	52	32	28	09	1.86	.25
V	09	-10	09	-10	19	41	1.44	.23
VI	60	10	60	10	18	59	1.58	.29

GIRLS

	Leg Velocity		Thigh Velocity		SW Thigh Vel.		Ratio	
Grade	Stride R	L	Stride R	L	Stride R	L	Mean	S.D.
I	44	37	42	72	47	40	1.30	.18
II	-03	28	40	44	30	18	1.47	.19
III	68	28	-16	-42	-11	20	1.46	.16
IV	-08	56	09	30	26	35	1.96	.31
V	-08	01	-03	12	08	05	1.39	.23
VI	-09	-08	-16	04	-40	04	1.47	.23

For boys, the ankle strength ratios are higher for Grades I to III and III to V. Grades II, IV, and VI show that strength has increased more than weight in the intervening year; but Grade VI has not increased as much as the other two grades. While girls in Grade III have a higher ratio than Grade I and Grade IV a higher ratio than Grade II, for Grade V and VI girls the ratio is not larger than Grades III and IV.

Knee-strength ratios and relationships to thigh velocities of supporting limb are shown in Table XLIII. These are consistently positive for boys and positive for girls in 8 of 12 possible r's. The ratio for Grade III is higher than that of Grade I for boys and girls; for Grade V higher than Grade III for boys only. The gains in ratio over the preceding year is smaller, the older the group; that is, the gain is greatest from Grade I to II and smallest from Grade V to VI.

Table XLIII - Knee Extensor Strength Relationships Means and Standard Deviations and r's with Thigh Velocity of Supporting Limb; Decimal Points for r's Omitted

GRADE	Stride R	L	Ratio Mean	S.D.
BOYS				
I	40	19	1.18	.14
II	30	38	1.56	.29
III	29	13	1.25	.21
IV	69	38	1.49	.32
V	30	09	1.36	.19
VI	56	19	1.42	.33
GIRLS				
I	50	72	1.17	.21
II	43	78	1.43	.21
III	-14	-41	1.37	.31
IV	13	23	1.60	.44
V	-04	63	1.23	.17
VI	-31	21	1.41	.22

8. Summary

a. Measures related to the run score

Among the measures taken from motion pictures of the run, four were found to be consistently related to the running score at all age levels. These are:

(1) the length of stride - the longer the stride, the faster the run;
(2) the time of foot contact - the shorter this time, the faster the run;
(3) the percentage of flight time (flight time divided by the sum of contact and flight times) - the larger this percentage, the faster the run;
(4) the velocity of supporting segments and of swinging thigh at take-off - the greater these velocities, the faster the run.

Some factors related to these four measures have been identified.

(1) Stride length is longer if at contact,
    (a) the hip is flexed more;
    (b) the thigh is closer to the horizontal;
    (c) the thigh is longer.
(2) Contact time is shorter, if at contact,
    (a) the ball of the foot makes contact or if when contact is made with the heel, the fore part of the foot is closer to the ground;

- (b) the leg is closer to the perpendicular;
- (c) the thigh is further from the horizontal;
- (d) the knee of the swinging limb is flexed more;
- (e) the thigh of the swinging limb is closer to the perpendicular.

(3) Percentage of flight time - no contributing factors identified.

(4) Angular velocities in the take-off phase are greater for
- (a) the supporting leg, if the ankle extensor strength per pound of weight is greater;
- (b) the supporting thigh if the ankle extensor and the knee extensor strengths per pound of weight are greater.

b. Age trends in related measures

Though the differences in age means of the measures listed above are small, there are indications that stride length increases, contact time decreases, and percentage of flight time increases with age.

At contact, there are indications that with age, the foot position changes from heel to ball contact; that the leg approaches the perpendicular;the thigh is further from the horizontal; the knee of the swinging limb is flexed more, and the thigh of the swinging limb approaches the perpendicular.

The thigh length, of course, increases with age and its effect on the linear velocity of the proximal end of the thigh may account for the lack of an age trend in the angular velocity of the thigh.

D. The Standing Broad Jump

1. Achievement scores

The distance of the film jump, unlike that of the length of the run stride, was measured directly at the time of filming. These scores with those taken during the week preceding the photographing are shown in Table XLIV. The "performance" scores are the means of the average of two of the best of four trials. The film scores are the means of one trial. The film means show a year by year increase except for Grade III boys and Grade V girls. The performance means also show this increase except for Grade V girls.

Table XLIV
Jump Scores of Photographed Subjects in Inches

	BOYS		GIRLS	
Grade	Film	Performance	Film	Performance
I	50.6	49.1	47.9	46.2
II	52.7	50.7	50.9	48.5
III	51.7	54.7	55.4	55.3
IV	58.1	56.4	61.9	60.0
V	62.0	61.7	58.6	57.9
VI	67.0	66.6	61.1	64.1

2. Film measures

Instead of the time-consuming frame by frame analysis, four frames were chosen for study on the basis of the investigators' understanding of the mechanics of the jump. These were (1) the take-off, the last frame of ground contact before flight; (2) the landing, the frame of first ground contact after flight; (3) the frame in which during take-off the thigh reached the perpendicular; (4) deepest knee flexion, the frame in which the knee flexion was greatest. The last two were chosen because previous study had shown that the thigh, moved in relation to the body by action at the knee joint and in space by the additional actions of foot and leg, was the major propelling force in the jump. In each of the four frames, seven measures were made, the angles at the ankle, knee, and hip and the angles with the horizontal of the foot, leg, thigh, and trunk. A total of 28 measures. In addition, the range of movement of each joint and segment from thigh perpendicular to take-off was calculated and also the velocity during this time, adding 14 more measures. These necessitated time measures from thigh perpendicular frame to take-off frame; time of flight was included; a grand total of 44 measures. Included in the correlation matrix were 17 additional measures of strength, segmental lengths, and the film and performance jump scores. Arm action was not included.

The procedures for obtaining measures from the film are those described under Film Measures in discussion of the run. Only those measures which were found to have consistent relationships to the distance and the mechanics of the jump will be included in the following discussion.

3. Measures directly related to jump score

The jump, as commonly measured, is the distance from the toes at take-off to the point of landing. Since the jump is primarily a projection of the body's center of gravity, the commonly measured score is achieved by three factors: (1) the lean of the body at take-off which carries the center of gravity beyond the toes; (2) the flight, the actual projection of the center of gravity; (3) the reach on landing which brings the contact point beyond the center of gravity.

a. Position at take-off

The positions of foot, leg, thigh and trunk at take-off are consistently related to the distance of the jump. See Table XLV. The positive r's with the foot measures show that the higher the foot is lifted from the ground, the further the center of gravity would be carried beyond the toes (unless compensated by segments above). The consistent negative r's with leg, thigh and trunk inclinations show that as these segments approach the front horizontal, they, too, add to the distance of the forward lean. When these segments are perpendicular to the horizontal, the measures are 90 degrees; as they slope forward, the measures are less than 90, and as they slope backward, the measures are more than 90.

Table XLV
Segmental Inclinations Relationships at Take-off in the Jump
r's with Jump Score; Decimal Points Omitted

BOYS

Grade	Foot	Leg	Thigh	Trunk
I	126	-079	-683	-367
II	500	-584	-243	-254
III	275	-093	-862	-391
IV	452	195	-864	-437
V	290	-113	-298	-297
VI	-140	-545	111	261

GIRLS

I	473	-247	-098	-293
II	258	-388	-816	-761
III	403	-326	-794	-805
IV	349	098	-519	-572
V	-041	-317	070	-440
VI	628	-753	-571	-460

The means of the segmental inclinations are shown in Table XLVI. Only the thigh means show an age trend, the thigh is closer to the horizontal as age increases. The importance of the thigh position is shown here for the thigh carries all the body weight above the knee joint.

Table XLVI
Segmental Inclinations Means at Take-off in the Jump
in Degrees; followed by Standard Deviations

BOYS

Grade	Foot		Leg		Thigh		Trunk	
I	79	13.4	43	6.1	62	9.0	63	10.9
II	84	10.7	44	8.3	59	10.0	66	7.0
III	81	7.9	42	5.4	59	7.8	67	8.2
IV	83	11.9	42	7.7	58	9.4	61	8.3
V	84	7.1	41	4.7	55	4.9	58	7.3
VI	90	6.7	40	4.5	54	5.3	64	7.8

GIRLS

I	83	5.9	40	7.6	70	7.7	73	9.3
II	87	7.5	38	7.2	67	11.0	67	8.7
III	91	6.8	40	6.0	59	6.9	70	10.5
IV	88	9.5	40	4.9	60	8.5	65	9.5
V	84	6.9	40	6.6	63	5.1	67	9.2
VI	84	9.9	42	6.3	60	8.6	66	8.2

b. Time of flight

The time of flight was determined by finding the time per frame for each film and counting the number of frames for each jump during which there was no ground contact. The r's between flight time and jump score are consistently positive, the longer the time, the longer the measured jump distance. See Table XLVII.

The means of flight time are also shown in Table XLVII. While the year to year means do not show a steady increase, there is a general trend toward a longer time in the air as age increases. The time for Grade VI boys is .047 seconds longer than that of Grade I boys, an increase of 14 percent; Grade VI girls' means is .039 seconds more than Grade I girls, an increase of 11 percent. As stated in time measures for the run, the exact timing is difficult, since the action is so rapid and the exact time of leaving and contacting the ground may be missed by the camera running at 64 frames per second.

Table XLVII
Flight Time of the Jump
Means and Standard Deviations in Seconds;
r's with Jump Scores; Decimal Points for r's Omitted

BOYS

Grade	r	Mean	S.D.
I	175	.327	.030
II	082	.368	.070
III	569	.366	.041
IV	511	.362	.019
V	469	.365	.032
VI	416	.374	.038

GIRLS

Grade	r	Mean	S.D.
I	-006	.329	.033
II	540	.331	.030
III	087	.355	.038
IV	596	.374	.028
V	364	.380	.030
VI	-097	.368	.018

c. Position at landing

At landing, the foot position does not show consistent relationships to the distance of the jump. Those with leg, thigh and trunk positions are consistent. The more the leg inclined, the further forward was the foot. The closer the thigh to the horizontal, the greater was its reach. As the trunk approaches the horizontal, it carries that mass forward and prevents falling backward on landing. See Table XLVIII.

Table XLVIII
Segmental Inclination Relationships at Landing in the Jump
r's with Jump Scores; Decimal Points Omitted

	BOYS			GIRLS		
Grade	Leg	Thigh	Trunk	Leg	Thigh	Trunk
I	244	368	-315	381	302	-128
II	243	826	-396	538	552	-637
III	346	570	-012	098	082	291
IV	-164	865	-642	097	497	-091
V	562	345	-016	172	510	118
VI	-434	551	643	369	492	-481

The means of the inclinations are shown in Table XLIX. There are indications of trends for a longer reach with the thigh and a greater forward lean of the trunk. However, the trend for the leg inclination is in the opposite direction; instead of reaching out to add to the distance, the leg is brought closer to the perpendicular, moving the foot backward. This would aid in preventing a fall backward.

Table XLIX
Segmental Inclination Means at Landing in the Jump
in Degrees; followed by Standard Deviations

BOYS

Grade	Leg		Thigh		Trunk	
I	117	5.9	141	8.8	45	17.1
II	114	6.3	147	9.6	52	16.2
III	111	7.9	134	7.0	40	22.4
IV	110	4.0	142	12.1	28	9.8
V	110	7.5	147	9.7	34	18.9
VI	111	4.3	151	16.2	37	12.0

GIRLS

I	106	5.6	139	8.7	49	15.7
II	107	4.1	145	9.0	52	18.6
III	105	4.3	136	12.8	49	7.9
IV	108	3.9	148	14.8	52	13.5
V	101	8.6	138	11.1	45	17.3
VI	104	3.8	143	16.9	41	16.8

4. Measures indirectly related to jump score

a. Segmental velocities during take-off

Thus far, the projection of the body through space has been discussed only in terms of the time of flight. Yet the speed during flight is also a factor determining the distance and this speed depends upon the speed of the segments during the process of taking off. Previous study had shown that the greatest speeds are attained after the thigh has reached a perpendicular position. Therefore, the degree of inclination of each segment at the time of thigh perpendicular was measured and also at the time of take-off. The differences between these is a measure of the range of movement of each segment and this range divided by the time between thigh perpendicular and take-off frames, provided a measure of the angular velocity of each segment in degrees per second. Only the velocities of thigh and trunk show consistent relationships to the jump score. Those with thigh velocity are generally higher and are more consistent than those with trunk velocity. It should be remembered that the thigh is moving forward and downward; the trunk is moving backward and upward. This movement of the trunk counterbalances the downward action of the thigh. (See Cooper and Glassow, Kinesiology, p. 141.) See Table L.

Table L
Thigh and Trunk Velocities during Take-off in the Jump
Means and Standard Deviations in Degrees per Second;
r's with Jump Distance; Decimal Points for r's Omitted

BOYS

Grade	Thigh r	Trunk r	Thigh M	S.D.	Trunk M	S.D.
I	521	311	365	106	232	78
II	175	200	394	80	270	84
III	816	-698	430	112	287	72
IV	868	781	407	93	273	52
V	396	303	417	98	213	35
VI	383	337	384	77	265	49

GIRLS

I	007	044	389	102	303	157
II	738	102	332	175	220	84
III	557	-075	494	124	319	96
IV	260	-006	490	189	291	134
V	104	378	385	91	215	102
VI	555	049	383	132	254	89

The means for thigh and trunk velocities are also shown in Table L. There is no general age trend in these angular velocity means, but as has been mentioned under the discussion of the run, the length of a segment as well as its angular velocity must be considered when evaluating its contribution to the projection force. To illustrate this point, the thigh length of Grade I girls will be considered as one foot in length; that of Grade VI girls as 1.25 feet. To determine the linear velocity of each thigh at the proximal end, the angular velocity is divided by 360 to determine the number of revolutions per second. For Grade I girls this is 1.08 (385 ÷ 360); for Grade VI girls, 1.05 (383 ÷ 360). To obtain the linear velocity of the proximal end of the thigh, these revolutions per second would be multiplied by (3.1416 x 2 x the length of the thigh). These products would be 6.79

feet per second for Grade I and 8.25 feet per second for Grade VI. Thus, though the angular thigh velocity of Grade VI girls is lower than that of Grade I girls, the contribution to propulsion force is greater due to the greater length of the thigh.

Since thigh velocity is an important factor in the propulsive phase of the jump, consideration was given to possible related factors. These could be knee joint action and speed of leg inclination. Both were found to be related to thigh velocity. The greater the velocity of knee extension and of leg inclination, the greater the thigh velocity. See Table LI.

Table LI
Velocity and Strength Relationships to Thigh Velocity
Decimal Points Omitted

BOYS

	Thigh Velocity r with		Knee Strength Ratio r with	
Grade	Knee Vel.	Leg Vel.	Knee Vel.	Thigh Vel.
I	815	116	152	-147
II	817	330	237	219
III	935	698	-122	008
IV	869	328	-158	027
V	839	681	571	635
VI	954	707	557	592

GIRLS

	Thigh Velocity r with		Knee Strength Ratio r with	
Grade	Knee Vel.	Leg Vel.	Knee Vel.	Thigh Vel.
I	703	279	514	368
II	639	-010	487	460
III	835	269	119	130
IV	973	317	226	357
V	940	710	797	764
VI	959	463	-264	-347

The means for knee velocity and leg velocity show no age tendency. See Table LII.

Table LII
Knee Extension and Leg Inclination Velocity Means in Degrees per Second

BOYS

Grade	Knee Extension		Leg Inclination	
	M	S.D.	M	S.D.
I	449	143	102	80
II	506	117	131	102
III	533	181	95	91
IV	486	134	85	63
V	526	153	94	64
VI	472	114	92	45
GIRLS				
I	512	183	127	107
II	486	188	152	70
III	662	180	176	97
IV	604	211	116	53
V	507	148	122	68
VI	511	161	128	52

Knee joint velocity was found to be positively related to knee extensor strength. The strength weight ratio (strength divided by total body weight) was used as the strength measures. The greater the strength per pound of weight, the faster the knee extension. See Table LI. Means for the strength ratios will be found in Table XLIII. There it was noted that the ratio was larger from Grade I to III to V, except for Grade V girls; for Grades II to IV to VI, the ratio decreased, except for Grade IV girls. During the period of study, younger children gained more in knee extensor strength in proportion to weight than did the older boys and girls.

An interesting relationship to thigh angular velocity is that of thigh length, which is negative. The longer the thigh, the slower its velocity. The r's are Grade I through Grade VI, decimal points omitted: boys: 062, -059, -084, -045, -042, -530; girls: -366, -558, -251, -426, -571, -333. Mean thigh lengths increase with age and are shown in Table XXX.

b. Position measures

The positions of body segments and its joints were examined for relationships to thigh velocity. At the position of deepest knee flexion, consistent relationships were found for the degree of flexion at the knee and for leg inclination. The more the knee is flexed and the more the leg is inclined forward, the greater the thigh velocity. See Table LIII. These two measures are related to each other, the more the leg is inclined, the more the knee is flexed. The r's Grades I through VI, decimal points omitted are: boys: 235, 115, 491, 600, 587, 448; Girls: 452, 863, 823, 064, -021, 518.

At the position when the thigh is perpendicular to the horizontal, only leg inclination shows a consistent relationship to thigh velocity, the more the leg is inclined, the greater the thigh velocity. See Table XLVIII.

At the take-off position, the greater the extension at knee and at hip joints, the greater the thigh velocity. Also, the more the thigh is inclined forward (as would be expected with the knee extension relationship), the greater the thigh velocity as the body projects itself. See Table LIII.

Table LIII
Position Measures Relationships to Thigh Velocity
Decimal Points for r's Omitted

BOYS

	Deepest Knee Flex		Thigh Perpend.	Take-off Position		
Grade	Knee	Leg	Leg	Knee	Hip	Thigh
I	-000	-013	098	877	744	-912
II	-326	-433	-123	470	-062	-556
III	-618	-595	-696	903	068	-828
IV	-184	-431	-351	407	185	-673
V	-639	-568	-681	390	-115	-471
VI	-345	-544	-429	414	188	-530
GIRLS						
I	-460	-459	-094	563	768	-726
II	-165	-265	-002	789	526	-874
III	-228	015	-025	373	485	-536
IV	-156	-465	303	590	468	-609
V	146	186	-296	588	602	-668
VI	-162	-621	-657	568	619	-928

The means for position measures will be found in Table LIV a and b. Only those of leg inclination at the deepest knee flexion show a definite age trend.

Table LIV (a)
Position Means in Degrees
Followed by Standard Deviations

BOYS

	At Deepest Knee Flexion				At Thigh Perpendicular	
Grade	Knee		Leg		Leg	
I	106	9.4	51	7.8	36	5.3
II	106	6.8	45	4.8	35	5.3
III	106	13.9	45	6.0	36	4.3
IV	111	7.7	42	4.7	35	4.6
V	111	12.2	44	7.5	34	3.1
VI	99	13.7	38	6.0	32	4.0

GIRLS

I	104	9.1	47	8.8	34	4.8
II	99	11.8	40	11.1	28	5.6
III	106	10.2	40	7.9	30	5.4
IV	101	8.9	39	5.0	33	4.4
V	99	6.4	37	3.3	32	5.4

Table LIV (b)
Position Means at Take-off in Degrees;
Followed by Standard Deviations

BOYS

Grade	Knee		Hip	
I	161	12.0	176	10.6
II	165	9.6	181	3.8
III	163	8.5	182	10.5
IV	165	14.6	180	8.1
V	166	6.3	182	4.9
VI	166	7.7	184	6.2

GIRLS

I	150	12.7	175	7.9
II	151	12.2	175	9.4
III	162	8.4	183	5.3
IV	160	11.2	177	8.8
V	157	7.9	179	10.7
VI	162	9.0	177	8.3

Summary

a. Measures related to the jump score.

The study of coordination in jumping performance began with the logical assumptions that the jump score is related to

(1) segmental positions at take-off,
(2) the time of flight,
(3) segmental positions at landing,
(4) velocities of the segments of the lower limbs during the take-off phase.

Each of these was examined by means of objective measures obtained from photographs of the subjects. Relationships within each age and sex group were found.

(1) In the take-off position, the jump score is better if
 (a) the heel is raised farther from the ground;
 (b) the leg, thigh and trunk are inclined farther forward.

(2) If the flight time is longer, the distance jumped is greater.

(3) At landing, the jump score is better if
 (a) the leg is farther from the perpendicular;
 (b) the thigh and trunk are closer to the horizontal.

(4) Greater angular velocities of the thigh and trunk at take-off result in better jump scores.

Since in the final take-off phase, only the thigh and trunk velocities were found to have consistent relationships to the jump score, factors which might affect the thigh velocity were examined. This choice was made on the basis of logic and previous study. The logic is the recognition that the thigh, as it rotates forward about its axis at the knee, carries approximately 85 percent of the body weight. The trunk at the same time is rotating backward, counteracting downward movement of the thigh. Hypothetically, its velocity is triggered by that of the thigh. Previous observations had not only emphasized the importance of thigh action, but had also shown it to be a distinguishing feature between high and low scoring jumpers.

It was found that thigh velocity is faster if
(a) knee extension is faster;
(b) leg velocity is faster;
(c) at the time of greater knee flexion in the preparatory crouch, knee flexion and leg inclination are greater;
(d) at the time the thigh reaches the perpendicular, leg inclination is greater;
(e) at the time of take-off, the knee and hip are closer to full extension and the thigh is inclined forward more;
(f) the strength per pound of body weight of the knee extensors is greater.

b. Age trends in related measures

The measures included in the preceding discussion were examined for age trend. While differences are small, there are indications that between seven and twelve years

(1) in the take-off position, the thigh and trunk move closer to the horizontal;
(2) the time of flight increases;
(3) at landing, the thigh and trunk move closer to the horizontal;
(4) at the position of deepest knee flexion, the leg inclination increases.

E. The Overhand Throw

1. Achievement scores

The time and distance measures needed to calculate the velocities of the photographed throws were taken at the time of filming. These velocity scores and those taken in the preceding week are shown in Table LV. The film scores are the group means of the photographed throw; the performance scores are the means of the average of the two best of four trials. As has been shown in many studies, boys' throws are much better than those of the girls. Grade VI girls' score is less than that of Grade III boys. In the run and jump, the differences are not as great.

Table LV
Throw Scores of the Photographed Subjects
in Feet per Second

	BOYS		GIRLS	
Grade	Film	Performance	Film	Performance
I	41.4	40.4	27.5	28.6
II	44.3	48.1	30.7	31.9
III	53.1	57.9	37.7	39.9
IV	56.0	55.7	40.4	41.1
V	59.1	64.5	36.9	43.5
VI	68.2	71.8	47.2	47.0

2. Film measures

Film measures of joint and segmental actions of the throw present problems not encountered in the run and jump. In the last two, action occurs mainly in a plane parallel to the film. In the throw, action occurs mainly in a plane which would be parallel to the film if the camera were overhead. While it is possible to obtain joint and segmental measures from film, when the camera is placed to the side if light weight bars are attached to body segments, this was not possible in the time in which the subjects were available. Therefore, the process measures for the throw are limited; some will be subjective judgments rather than quantitative measures.

3. Body rotation

In the throwing of children ages two to seven years, Wild observed that the pattern developed from anterior-posterior movements of arm and trunk to movements in the transverse (horizontal) plane and that stepping forward with the left foot did not occur until six and a half years in boys, while the girls' pattern at that age was more immature. (Res. Quart. 9:3, 20, 1938).

a. Full turn to the right

The film was observed during the preparatory backswing and subjectively evaluated as a full turn or less. A full turn was one in which the trunk faced the camera, a 90 degree turn from the direction of the throw. In terms of the percentage at each grade level, making a full turn, these judgments were:

Grade	Boys	Girls
I	71	38
II	79	77
III	91	33
IV	100	66
V	93	55
VI	100	91

There is a gain for each grade and sex from the first to the second year. Only among the first grade girls was there practically no turn to the right; this was observed in 31 percent of that group.

b. Step forward

In skilled performers, trunk rotation to the right is executed as the left foot is raised from the ground and carried forward in the direction of the throw. The pelvis is thus supported by the lower right limb and the left side is free to swing to the right carrying the trunk with it. The step facilitates the rotation of the trunk.

The number of children who stepped forward with the left foot (right for left handed throwers) were observed in the film. In percentages, these were:

Grade	Boys	Girls
I	14	8
II	79	39
III	36	0
IV	55	17
V	93	18
VI	100	18

Each group gains in the number who step forward with the left foot from the first to the second year of observation except Grade VI girls. The percentages are not as large as those making a full right facing, since some children in the starting position faced to the right.

c. Length of stride

Since skilled performers take a long stride in delivering a ball the greatest distance between the feet, when both were on the ground during the back and forward swing, was measured. The measured distance in feet was:

Grade	Boys	Girls
I	0.50	0.40
II	1.50	0.95
III	1.31	0.69
IV	1.61	1.01
V	2.39	0.73
VI	2.65	1.32

These means show an increase in mean length of distance between the feet during the year of observation. They also show an age trend, an increase from Grade I to III to V and from Grade II to IV to VI.

4. Lever length for hip rotation

The contribution of the rotating trunk to the force imparted to the ball at the time of release depends upon the speed of the rotation and upon the distance between the hip and the ball. In the second year as the pictures were taken, a second camera which took a rear view of the performer was included. From these films, it was possible to measure the distance between the ball and the estimated position of the hip at the time of release. These, then, are available for Grades II, IV, and VI. The means of these distances in feet were:

Grade	Boys	Girls
II	1.52	0.92
IV	1.49	1.29
VI	1.77	1.23

The lever length for the hip action, if joint positions were the same, would increase with age, growth of arm length and trunk width. While there is in Grade VI a length which is greater by 3 inches for boys and 3.7 inches for the girls, there is not an increase from Grade II to IV for boys and from Grade IV to V for girls. For the boys in Grade IV, the decrease appears to be due to the position of the trunk. The majority of this group, 73 percent, leaned away from the ball at the time of release. For the girls in Grade VI, the decrease appears to be due to arm position. While 81 percent of this group had an advantageous position of the upper arm, one close to 90 degrees of abduction, more than half of these (45 percent of the total group) shortened the lever by almost 90 degrees of elbow flexion. The remaining 18 percent shortened the lever by extreme abduction of the upper arm, bringing the entire arm closer to the supporting hip.

5. Summary

On the assumption that, during the throwing act, the trunk is faced at least 90 degrees away from the direction in which the ball is to be thrown, the number of children in each grade and sex group who made such turns was subjectively determined from the film. Since the turn is facilitated by a stride, which may be assumed before the action begins or achieved by a step as the arm and trunk move , the length of the stride was measured in feet and the number of children who stepped was subjectively determined. In all factors - turning, stepping, length of stride -- each group improved during the year between observations.

Previous observations had shown that in skilled performers, at the time the ball is released, the arm is abducted almost to the horizontal with the elbow close to full extension. This position increases the distance between the supporting hip and the ball, a distance which cannot be measured in side view pictures. In the second year of this study, a camera was placed to the rear as well as to the side to film the throws and hip to ball measures were made for Grades II, IV, and VI. While Grade VI means are better than those of Grade II, the progression from grade to grade is not consistent.

Age trends in these observations are indicated by the means of stride lengths only.

Chapter IV. General Summary

I. Background

Motor development and motor abilities of elementary school children have long interested and concerned the investigators of this study. Aware of the scarcity of available information, especially for the ages six to nine years, they had been collecting data in an elementary school for the six years immediately preceding the initiation of this project. In those observations were included (1) performance scores of the run, jump, and throw; (2) strength measures of eight muscle groups, and (3) photographic recordings of running, jumping, and throwing. These accumulated data provide a source for many types of information: age-sex mean scores for the three basic skills and for the eight strength measures which are cross sectional and longitudinal; relationships between these performance scores and strength measures; from the photographs, the sequence, range, and velocity of joint actions can be determined and the comparisons can be made of age and sex groups and of high and low scoring performers. Publications and theses based on these six years of observations which are pertinent to the present study are included in the references listed at the end of Chapter I.

During these six years, the primary purpose was to measure and record characteristics of children. In the sixth year, circumstances prompted consideration of future procedures. Chief among these was the termination point for certain measurements. Annual strength measures and photographing of performance had been limited to two groups, beginning when each was in the first grade and ending when each was in the sixth grade. Thus, the measurement of one group would end with the sixth year; the other group would be observed for another year.

It was reasoned that the accumulated data should be organized and interpreted before more were collected. Yet, it was also reasoned, the situation provided an opportunity which should be utilized. The grade means which had been collected were essentially uniform from year to year. Would it be possible to make changes in the school program which might affect the measured characteristics? The previously collected scores could serve as a control with which new scores could be compared.

The investigators believed, as do many physical educators, that elementary school physical education programs are not as demanding as they could and should be in terms of organic stimulation and in development of motor skills, especially in the first two grades. Therefore, it was decided that if the needed approval and cooperation could be obtained that the observations would be continued for another two years, during which efforts would be made to improve the physical education program. This report is concerned with this second two year project.

II. Objectives

In general, the objectives of the present study are (1) to add to observations of certain aspects of children's motor behavior and (2) to compare the outcomes of an experimental physical education with outcome obtained in a control situation and with other avilable data.

The observations which will add to information concerning motor development and motor abilities in Grades I - VI include

(1) performance scores in three fundamental skills - run, throw, jump;

(2) strength scores of eight muscle groups - hip flexors and extensors, ankle and knee extensors, elbow and wrist flexors, shoulder adductors and medial rotators;

(3) six performance scores which have been recommended as measures of Physical Fitness - run, throw, jump, sit-up, pull-up, shuttle run;

(4) selected coordination measures in running, jumping, throwing.

The effects of the experimental program were compared to other data, using the performance scores in the three fundamental skills, the strength scores, and the sex measures of Physical Fitness.

III. Experimental Procedures

A. The subjects

The subjects included all children who were in the first, third, and fifth grades in the experimental school when the project was initiated. Since the observations covered a two year span, these subjects were in the second, fourth, and sixth grades in the second year. Initial enrollments were Grade I - 49 boys, 38 girls; Grade III - 22 boys, 34 girls; Grade V - 20 boys, 29 girls. These numbers will vary slightly at each observational period. Performance scores in the three fundamental skills and in the three additional Physical Fitness measures were obtained for all children in the above groups who were available at the time.

The number of subjects whose strength was measured and whose performances were photographed was limited to 15 girls and 15 boys from each grade who were randomly selected in the final weeks of the first year, a total of 90. This number was decreased slightly by changes in the school enrollment in the second year.

B. Measurement techniques.

In this summary, descriptions will be included when the procedures differ from those customarily employed.

1. The run was timed for the last 30 yards of a 35 yard run.
2. The standing broad jump, as usually measured.
3. The overhand throw was measured as velocity in feet per second, a procedure which necessitates consideration of gravitational force as well as the horizontal distance which the ball travels.
4. Pull-up, sit-up, and shuttle run were administered as recommended in the AAHPER Youth Fitness Manual with one exception. The score for girls was obtained in the situation recommended for boys.

5. Strength measures were obtained with the cable tensiometer as described by Clarke.

6. Coordination measures were obtained from motion pictures. This necessitated photographing and study of the films. The pictures were taken out-of-doors, using a four inch camera lens and 16 mm black and white film. The camera speed was set at 64 frames per second; its distance was 97 feet for the run; 65 feet for the jump; 50 feet for the throw.

Measurements from the film were made by projecting one frame at a time on a film reader, the Recordak (Recordak Corporation, Chicago). Key frames were selected for each performance; three for the run, four for the jump, four for the throw. These were:

(a) for the run, (1) the last frame of foot contact before flight, (2) the first frame of foot contact after flight, (3) the frame in which the supporting leg reached a perpendicular to the ground;

(b) for the jump, (1) the last frame of foot contact before flight, (2) the first frame of foot contact after flight, (3) the frame in which during take-off the thighs reached a perpendicular to the ground, (4) the frame in which during the crouch preceding take-off, the knee flexion is greatest;

(c) for the throw, (1) the frame in which the torso is turned furthest from the direction of ball flight, (2) a frame in which the forward foot is placed on the ground, (3) the frame in which the ball is released.

From these frames, joint angles and angles of segments with the horizontal, and linear distances were measured.

C. The experimental program

The experimental program was planned by four physical educators - the two instructors in the experimental school who had taught there in the preceding years, a research assistant who had had elementary school experience, and one of the project investigators. The teaching was done by the first three. In the year the project was initiated, the city had reduced the physical education time in the lower grades, but approval was granted to maintain the time schedule of previous years by including the research assistant in the teaching staff. The assistant taught the two lower grades, one of the instructors, the girls of the upper grades one, the boys of the upper grades.

In consultation, the four educators planned the program for the two years, attempting to make it one which would demand strength and develop skill and one which would be organically stimulating. The aim was to plan activities which would be progressive within and between years and one which would be child rather than game centered.

IV. Treatment of Measures

A. Observations

1. For the performance scores in the three fundamental skills, means and standard deviations were calculated for the beginning of the first year and for the end of the first and second years for each grade and sex group. .

2. For the three additional Physical Fitness Measures, means were calculated for the end of each year for each grade and sex group.

3. For the strength scores, means were calculated for the end of each of the two years for each age and sex group.

4. For the coordination measures:

a. for the jump, 100 measures for each individual were combined with 17 strength and anthropometric measures and correlations between these and the mean and standard deviation of each were calculated. The resulting r's were inspected and those which in each age and sex group had a consistent relationship to the speed of the run were inspected for age trends as shown in the means;

b. for the jump, 61 measures were correlated and factors related to the distance of the jump were selected and the means of these inspected for age trends by the methods described for the run;

c. for the throw, two factors known to be related to the distance of the throw were determined by inspection; two were linear measures taken directly from the film.

B. Comparisons

1. Performance means for the run, jump and throw of the experimental groups were compared to those of the control groups by inspection.

2. Means for the Physical Fitness measures were compared to those of the AAHPER norms and to a 1954 compilation of available scores for the run, jump, and throw by inspection.

3. Strength gains for the experimental groups were compared to those of the control groups by covariance analysis.

V. Results

A. Observations

1. Performance scores in the run, jump, and throw.

Since scores of the control groups are included, the number of subjects included in the report is larger than the number of experimental subjects.

Mean scores, in seconds for a 30 yard run, are reported for 512 boys and 567 girls, Grades I - VI and means and standard deviations for 246 boys and 200 girls, Grades I - VI.

Mean scores in inches for the standing broad jump are reported for 652 boys and 565 girls, Grades I - VI and means and standard deviations for 256 boys, Grades I - VI and for 146 girls, Grades III - VI.

Mean scores in feet per second for the overarm throw are reported for 439 boys and 434 girls, Grades I - VI and means and standard deviations for 110 boys and 133 girls, Grades III - VI.

2. Physical Fitness measures

Means scores for the run, jump, throw, sit-up, pull-up, and shuttle run are reported for 174 boys and 177 girls, Grades I - VI. For the first three standard deviations are also reported; for the last three, the ranges of the scores.

3. Strength measures

Means for the eight strength measures for 80 boys and 78 girls are reported. Each of these groups were measured twice, once at the end of each year. Thus, the means are those obtained from scores taken at the end of each of the six grades.

4. Coordination measures

a. The run

Within each age and sex group, it was found that the run is faster if the stride is longer, the time of foot contact is shorter, the percentage of flight time (flight time divided by the sum of flight and contact times) is longer, and the velocity of the supporting segments is faster at the time of take-off.

The stride is longer if the hip of the contacting limb is flexed more as the foot makes contact after flight and if, at this time, the thigh is closer to the horizontal and if the thigh is longer.

The contact time is shorter if the ball of the foot makes the first contact or if the heel makes contact, the fore part of the foot is closer to the ground; if the leg of the contacting limb is closer to the perpendicular; if the thigh of the contacting limb is further from the horizontal; and if at contact the knee of the swinging limb is flexed more and the thigh of that limb is closer to the perpendicular.

Angular velocity at take-off is greater in the supporting leg if the ankle extensor strength per pound of weight is greater, and greater in the supporting thigh if the knee extensor strength per pound of weight is greater.

Though the differences between age means are small, there are indications that stride length increases, contact time decreases, and percentage of time in flight increases from Grade I to Grade VI. Also as the foot reaches the ground at the end of flight, the contact changes from heel to ball, the knee of the swinging limb flexes more and the thigh of that limb approaches the perpendicular.

b. The standing broad jump

The jump is longer if at take-off the foot, leg, thigh and trunk are inclined further forward; if at contact after flight, the leg is further from the perpendicular and the thigh and trunk are closer to the horizontal and if at take-off the velocities of the thigh and trunk are greater. Thigh velocity is greater if at take-off knee extension and leg velocity are greater, if at the time of greatest knee flexion in the preparatory crouch the knee is flexed more and the leg is inclined further forward; if at the time the thigh reaches perpendicular in the take-off the leg is inclined further forward; and if at the time of take-off the knee and hip approach full extension and the thigh is inclined further forward; and if the knee extensor strength per pound of body weight is greater.

Differences between age means in the above factors are small, but indications suggest that with age, in the take-off position, thigh and trunk move closer to the horizontal; the time of flight increases; at landing, thigh and trunk move closer to the horizontal and the leg moves closer to the perpendicular.

c. The overarm throw

With age, a greater percentage of children turn at least 90 degrees from the direction of the throw, a greater percentage take a step forward and the length of that step increases.

B. Comparison of the outcomes of the experimental program

1. In the three fundamental skills, the experimental means were consistently better than those of the control groups in the run; there were no consistent differences in the jump and throw.

2. In the Physical Fitness measures taken as a whole, the experimental group scores were superior. However, these must be viewed with caution since there were many differences in methods of measuring.

3. In strength scores

The experimental program in general resulted in greater gains in strength than did the previous program. The superiority is clearly evident in the muscle groups of the lower extremities and less clearly defined in the upper. The gains were greater for the younger children than they were for the older elementary school children.

VI. Conclusions

Tabulations of motor characteristics and strength measures are additions to available information regarding the six through twelve years groups. These are especially valuable for the first three years of that age span for which few observations have been reported.

From other sections of the project, conclusions may be drawn.

1. Since mean coordination measures from six to twelve years of age differ only slightly,

a. improvement in the mean scores for the run and jump in these years can be attributed in large degree to skeletal growth;

b. the slight coordination changes which do occur may be due to practice rather than to an age maturation factor.

2. Specific muscle groups can be strengthened, between ages six and twelve years, through participation in a school physical education program and gains are greater when efforts are made to stress vigorous activity. There is no need for a normal child to exercise a specific joint action, apart from its participation in a movement pattern, to increase the strength of a particular muscle group.